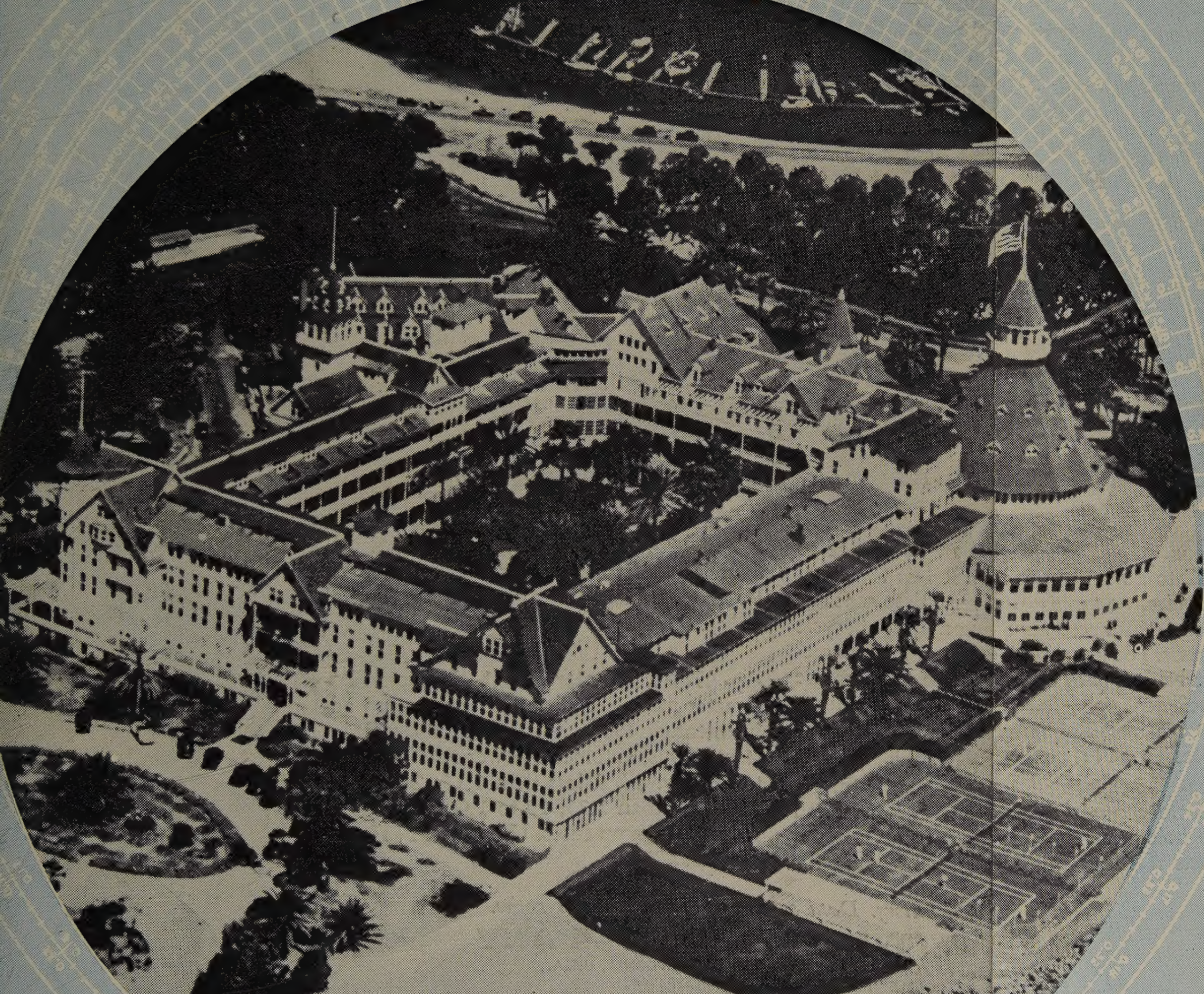
APRIL 1960
VOLUME 3 • NUMBER 4

- Microwave Engineering Aspects of Electron Linear Accelerators — Part I
- Microwave Radiometry — Part I
- The Effect of Silver Plating on Attenuation at Microwave Frequencies
- Simple Calculations of Waveguide Wavelength
- A Set of Practical Design Data for Quarterwave Coaxial (TEM) Cavities

he microwave journal



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1960 PGMTT NATIONAL SYMPOSIUM PROGRAM

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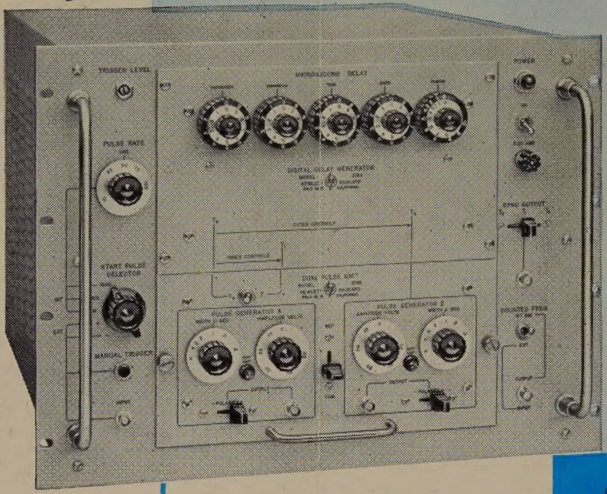

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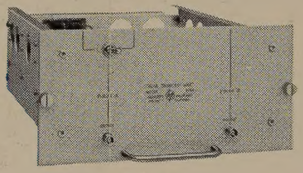
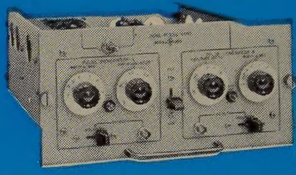


219A



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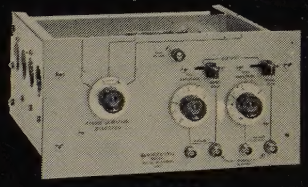

219C

Time measurement and pulse simulation in radar, loran, Tacan, DME, oscilloscopes, computers, fast gates, pulse code systems—almost any kind of time measurement single- or double-pulse simulation is now yours quickly and accurately with 218AR Digital Delay Generator.

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Time Interval Range:	1 to 10,000 μsec
Accuracy:	± 0.1 μsec ± 0.001%
Digital Adjustment:	1 μsec steps, full range
Interpolation:	Variable 0 to 1 μsec
Input Trigger:	Internal 10 cps to 10 KC; External 0 to 10 kc pulses, also sine wave
Jitter:	0.02 μsec or less
Recovery Time:	50 μsec or 10% of interval, whichever is greater
Sync Output:	50 v pos. pulse, 0.1 μsec rise time
1 MC Output:	1 v pulses, 500 ohm impedance
Price:	-hp- 218A, $2,000.00 -hp- 219A Dual Trigger Unit, $100.00 -hp- 219B Dual Pulse Unit, $450.00 -hp- 219C Digital Pulse Duration Unit, $350.00

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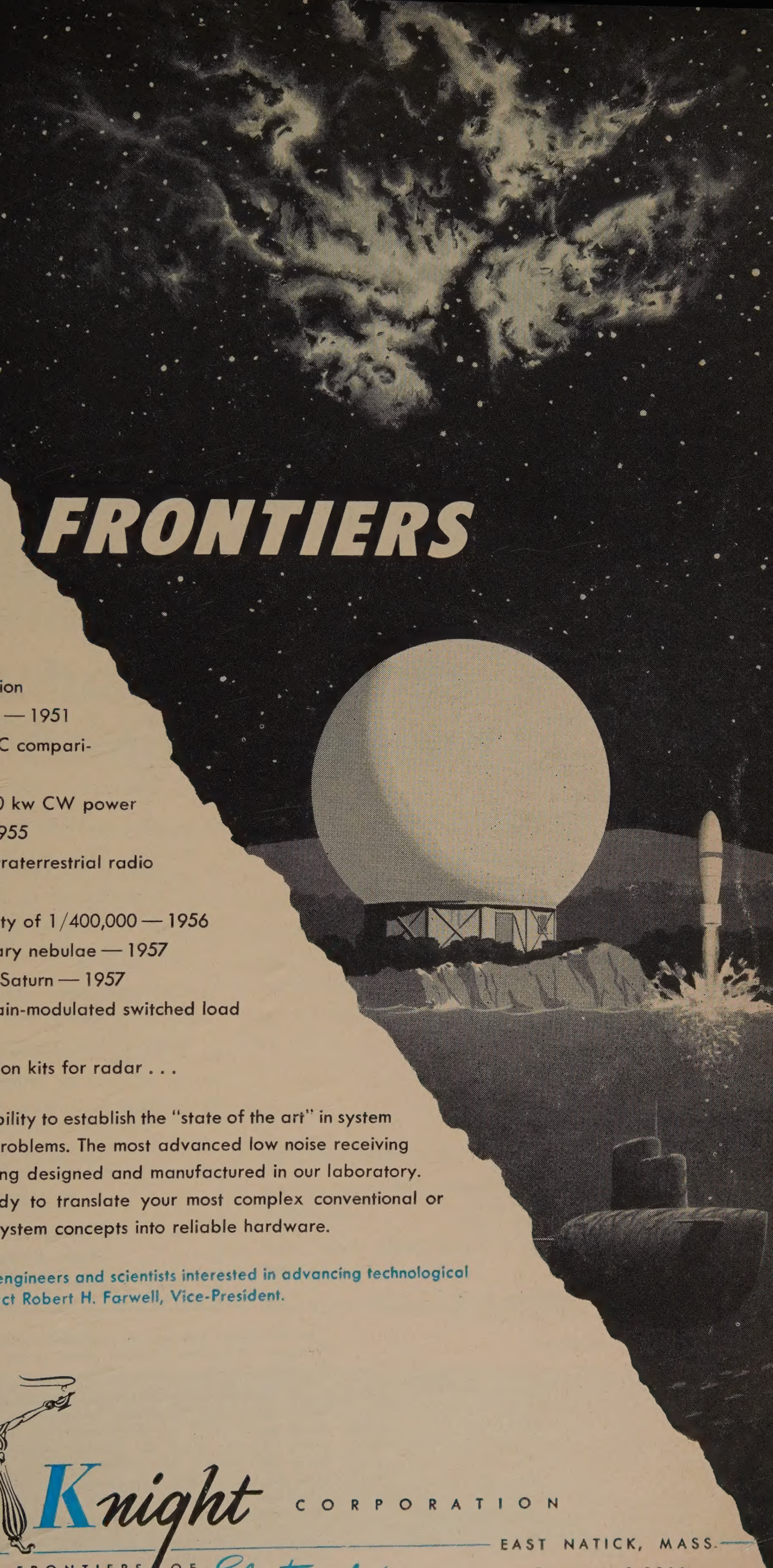

AT THE FRONTIERS

FIRST detection of 21-cm radiation from interstellar hydrogen — 1951
FIRST commercially available DC comparison radiometer — 1953
FIRST commercially available 50 kw CW power amplifiers at 960 Mc — 1955
FIRST typewritten display of extraterrestrial radio radiation — 1956
FIRST radiometer with a sensitivity of 1/400,000 — 1956
FIRST radio detection of planetary nebulae — 1957
FIRST radio detection of planet Saturn — 1957
FIRST commercially available gain-modulated switched load radiometers — 1959
NOW developing maser conversion kits for radar . . .

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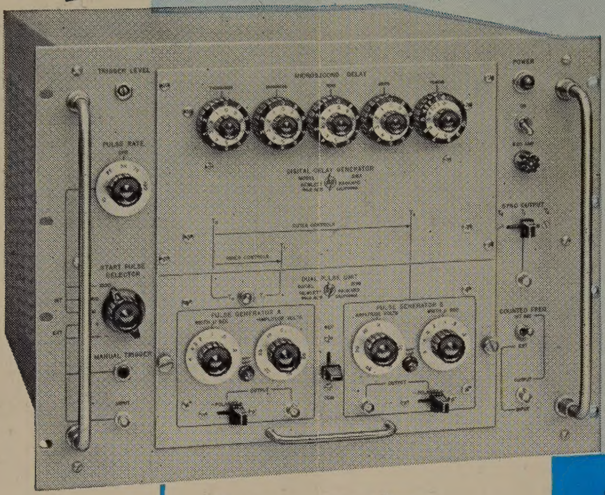

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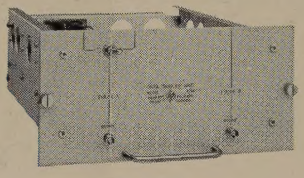

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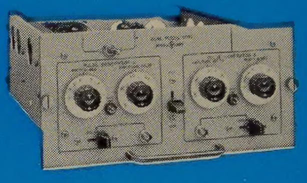

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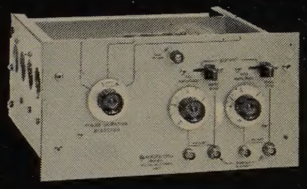

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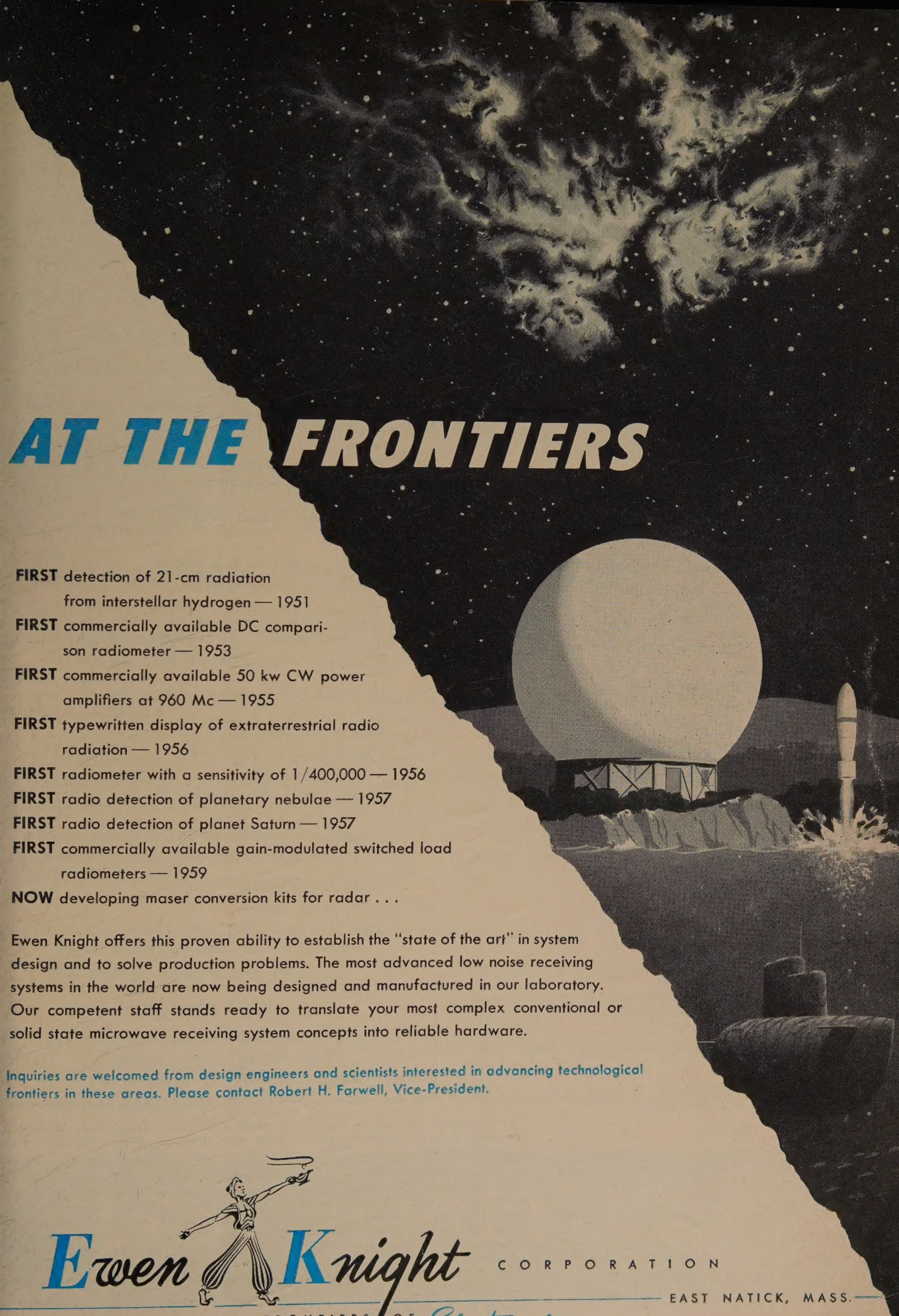

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APRIL, '60 vol. 3 - no. 4

the microwave journal

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Parametric Diode Q Measurements

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Operates more Klystrons than any comparable unit!

This new Narda Wide Range Klystron Power Supply operates virtually all medium and low voltage Klystrons, as well as some high voltage tubes (at reduced power output). It literally operates more Klystrons, including Sperry and Varian tubes, than any other unit in its price range!

What's more, all components, including tube sockets, are operated within manufacturers' ratings. (Many other supplies exceed plate-cathode, cathode-filament or socket-ground voltage ratings.)

Want more information about this new Power Supply that gives you greater versatility and longer trouble-free service at lower cost? Then write us for complete spec sheets. Ask, too, for your free copy of our complete catalog. Address: Dept. MJ-6.

FEATURES

- **250-700 volt Beam Supply, 0-65 ma.**
- **0-1000 volt Reflector Supply**
- **Accurate Ten-Turn Dial Calibration**
- **5 mv max. Reflector Ripple**
- **Diode Protection Circuit**
- **Oil Filled Capacitors in High Voltage Filters**
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New space-scanning radio telescope equipped with *Styroflex® Coaxial Cable*

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Six "runs" of Styroflex® coaxial cable connect the 85-foot parabolic antenna with the control building. These "runs" are used to relay radio waves picked up from outer space by the telescope.

The job of feeding these low-energy radio waves to the control center calls for a high frequency cable with a low inherent noise level. The low loss and low noise to high signal ratio of Styroflex® cable provide the ideal answer to these operational requirements. An additional advantage is the long operating life of this coaxial cable, regardless of clima conditions.

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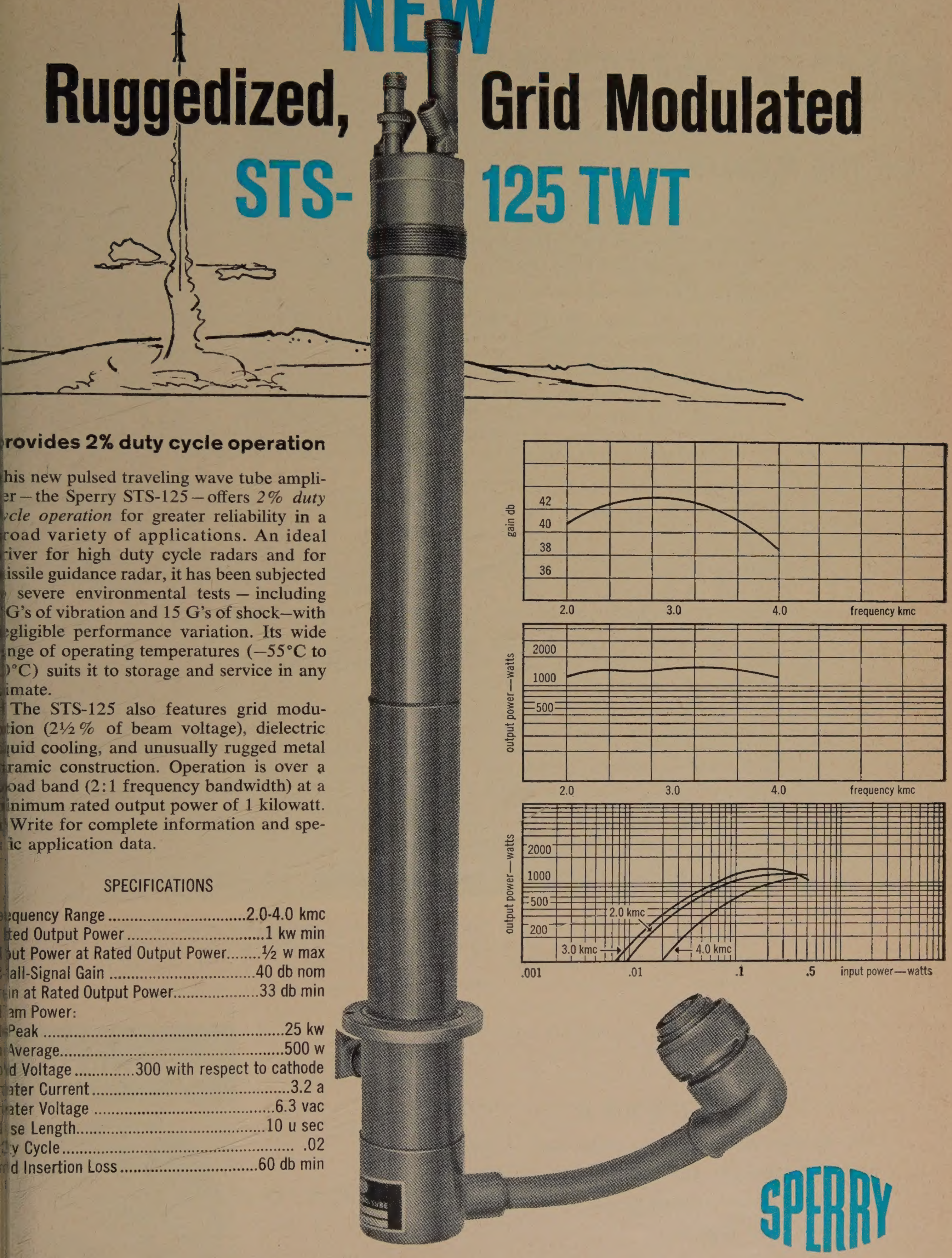

rovides 2% duty cycle operation

his new pulsed traveling wave tube ampli-
er – the Sperry STS-125 – offers *2% duty
cle operation* for greater reliability in a
road variety of applications. An ideal
iver for high duty cycle radars and for
issile guidance radar, it has been subjected
severe environmental tests – including
G's of vibration and 15 G's of shock–with
gligible performance variation. Its wide
nge of operating temperatures (–55°C to
)°C) suits it to storage and service in any
imate.

The STS-125 also features grid modu-
tion (2½% of beam voltage), dielectric
uid cooling, and unusually rugged metal
ramic construction. Operation is over a
oad band (2:1 frequency bandwidth) at a
inimum rated output power of 1 kilowatt.

Write for complete information and spe-
ic application data.

SPECIFICATIONS

quency Range	2.0-4.0 kmc
ted Output Power	1 kw min
ut Power at Rated Output Power	½ w max
all-Signal Gain	40 db nom
in at Rated Output Power	33 db min
am Power:	
Peak	25 kw
Average	500 w
d Voltage	300 with respect to cathode
ater Current	3.2 a
ater Voltage	6.3 vac
se Length	10 u sec
y Cycle	.02
d Insertion Loss	60 db min

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MICROVIEWS OF THE MONTH

35 ▶

MICROWAVE ENGINEERING ASPECTS OF ELECTRON LINEAR ACCELERATORS - Part I

Alfred E. Barrington

During the past thirty years, machines for the acceleration of charged particles have become increasingly important tools for scientific research. One of the most recent members of the accelerator family, the electron linear accelerator, utilizes multi-megawatt microwave power tubes and presents a striking example of the interplay between particle physics and microwave engineering techniques. Part I of this survey discusses some of the theoretical aspects of accelerating waveguide structures.

41 ▶

MICROWAVE RADIOMETRY - Part I

Donald B. Harris

Knowledge of the universe outside of the earth's atmosphere has been greatly expanded by the use of radio astronomy techniques. This paper deals not with the large field of radio astronomy, but with instrumentation used in this art. Part I presented here discusses the basic theory of operation of microwave radiometers.

47 ▶

THE EFFECT OF SILVER PLATING ON ATTENUATION AT MICROWAVE FREQUENCIES

Hans C. von Baeyer

In the past few years, a considerable literature has grown on the subject of the effect of surface quality of microwave components on attenuation. This report has three purposes:

1. To formulate a common terminology in order to facilitate comparison between the results of various investigators.
2. To give a brief summary of the results obtained with particular reference to silver plating.
3. To gather a bibliography on the subject.

51 ▶

SIMPLE CALCULATIONS OF WAVEGUIDE WAVELENGTH

Jorgen P. Vinding

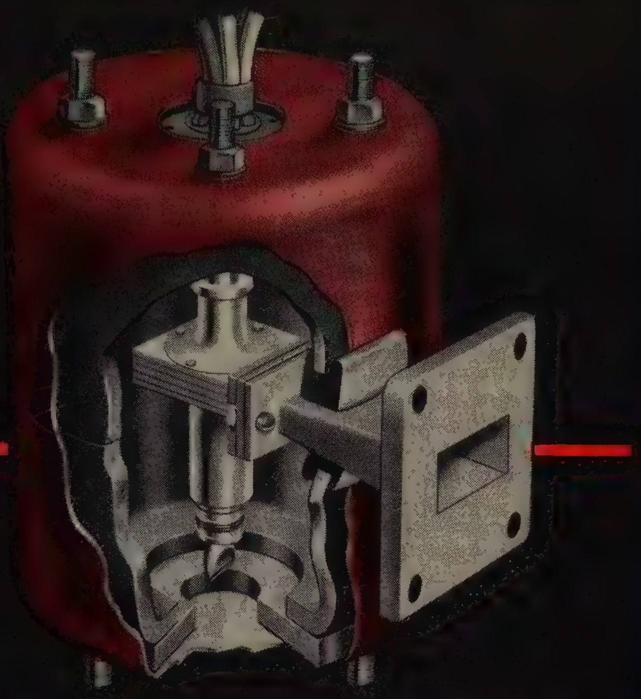
These are calculations that many microwave engineers must make every day. Here are slide-rule procedures which, we hope, will make these tasks simpler.

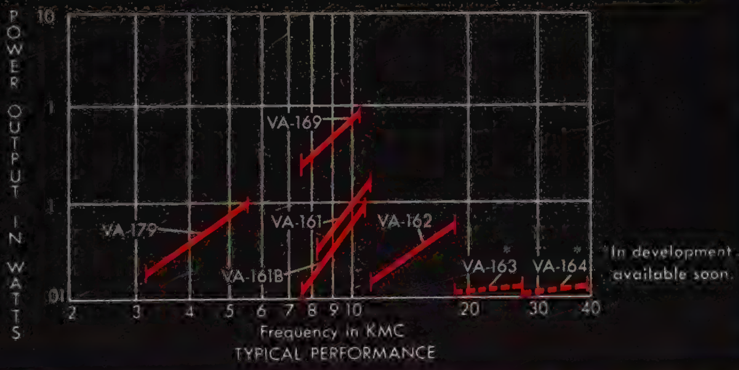
OUR COVER

This month's cover shows an aerial view of the Hotel del Coronado, scene of the 1960 PGMTT Symposium, in the Coronado suburb of San Diego, California. (See page 82.)

FROM VARIAN:

A LINE OF RUGGED, PM FOCUSED BACKWARD WAVE OSCILLATORS





Varian now offers a line of permanent magnet focused backward wave oscillators in frequency ranges to cover a wide variety of circuit application requirements. All models feature small size, low voltage operation, long life expectancy and rugged construction. These tubes are available either from stock or on short delivery schedules. The metal and ceramic construction offers the most reliable tube at the lowest cost and assures dependability in severe environments. Typical applications for Varian BWO's are: signal generators, electronic countermeasures and systems requiring frequency agility.

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- FOUR regular VSWR scales plus one expanded
- Meter scales automatically normalized when switching from regular to expanded
- Large 5¾″ meter with 1% linearity
- Continuous gain control over 15 db range
- Continuously variable bandwidth control
- Front panel meter monitors bolometer bias current

SPECIFICATIONS:

Frequency: 1,000 cps; adjustable over a 2% range.

Sensitivity: 0.02 μv at minimum (4 cps) bandwidth. 0.1 μv at maximum (40 cps) bandwidth.

Noise Level: 5db below full scale (0.007 μv at minimum bandwidth).

Amplifier Q: 250 at 4 cps; 25 at 40 cps.

Bandwidth: Continuously variable from 4 to 40 cps.

Calibration: Square Law. Meter reads SWR, db.

Range: 85 db. Input attenuator provides 70 db in 5 db steps. Gain control provides 15 db adjustable. Accuracy ±0.1 db per 10 db. Maximum cumulative error of ±0.2 db at 40 cps bandwidth.

Scale Selector: Expanded, Regular, and Bolometer Current. Meter scale always normalized when switching from expanded to regular.

Meter Scales: SWR: 1-4; SWR: 1.8-6; SWR: 3.2-10; SWR: 6-15; Expanded SWR: 1-1.3; db: 0-10; Expanded db: 0-2.3.

Input Selector: 220,000 ohms; Crystal; Bolometer. Bias provided for 8.75 ma bolometer or 4.3 ma bolometer. Bias adjustable ±15%. A bolometer protective circuit permits any switching operation or cable connect-disconnect without damage to bolometer.

Output: Jack for 1500 ohm recorder, 1 ma full scale deflection.

Input Connector: BNC Jack.

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WHY THE MICROWAVE ENGINEER SHOULD JOIN PGMTT

RICHARD F. SCHWARTZ

ASSISTANT PROFESSOR OF ELECTRICAL ENGINEERING
The Moore School of Electrical Engineering
University of Pennsylvania • Philadelphia, Pennsylvania

HIS EDITORIAL IS DIRECTED on the surface toward the pecific question of why a microwave engineer should in the IRE Professional Group on Microwave Theory nd Techniques. It is impossible to answer this ques- on unless the reader is convinced of the worth of ofessional societies in general. The writer has fre- uently been shocked by finding engineers (and fairly mpetent ones at that) who could see no value in chnical associations. The argument advanced is usu- ly that the journal of a particular society can be ad in a library without one's being a member, or at the cost of belonging is too great. In these days spiraling inflation it is all too easy to eliminate such penses from ever-tightening family or personal dgets.

Professional societies are not new, of course. It may difficult to trace the exact history, but it would em reasonable to assume that professional organiza- ons, like trade unions, have roots in the guilds of edieval Europe. Here, people of like interests banded gether for the protection and regulation of the rious callings. At a somewhat later date the in- llectual elite organized societies for the exchange of eas, the honoring of cultural achievements, and the omotion of learning. In this manner the Royal ociety of Great Britain and the French Academy of iences were born. Most modern professional societies ll somewhat between these two extremes.

It was, of course, inevitable that such groups should ourish. Man is by nature gregarious. He must communicate with others. The success of our civilization is, in fact, due very largely to man's sociability — born partly from the need for protection — for with interdependency came specialization, the exchanging of ideas between men of common interest, and the flourishing of culture and technology.

Present-day professional societies vary greatly in objectives, but among engineering organizations one of the prime aims is the promotion of the exchange of technical information and the reporting of new engineering developments. No one working in design or development engineering can do a creditable job for long without referring to specialized periodicals, a large percentage of which are published by technical societies. It would be well at this point for the young engineer to pause and ask himself: "Do I use the technical societies' journals in my work?"

If the answer is "yes," let the young engineer next ask: "Who should support, govern, and write for these publications? Salesmen? Businessmen? Advertising agencies? Or engineers?" It shouldn't take much reflection to decide that engineering societies' magazines should be largely by and for engineers.

As for the technical meetings, the critic of technical societies will claim that these are dull affairs at which he can learn nothing. Most of us will agree that the oral presentation of technical papers usually leaves something to be desired. Nevertheless, such a presentation has some value. First, it is valuable to the per-

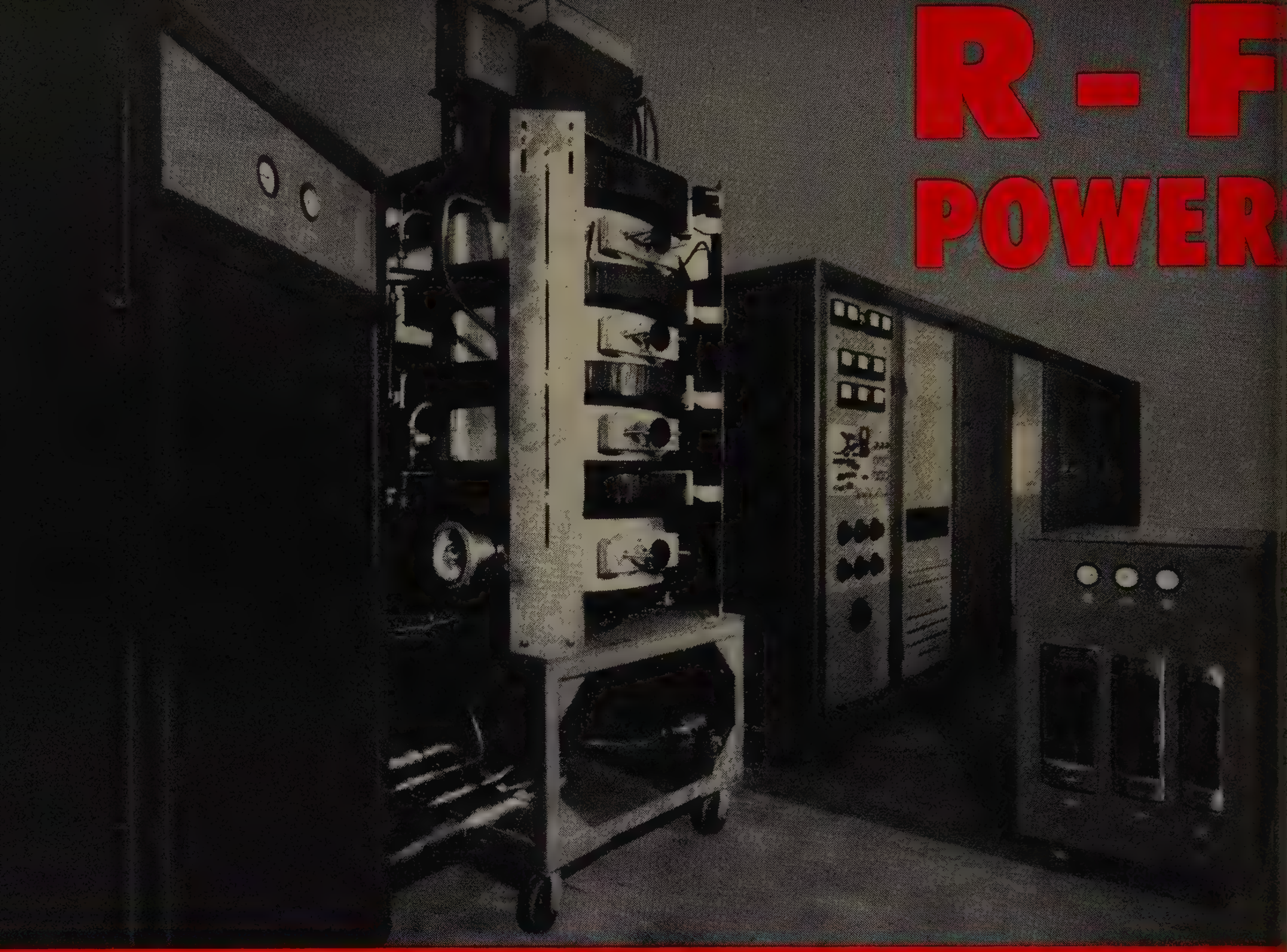
(*Continued on page 11*)

ICHARD F. SCHWARTZ was born in Albany, New York in 1922. e received the B.E.E. and M.E.E. degrees in 1943 and 1948 respec- vely, from Rensselaer Polytechnic Institute, and the Ph.D. degree electrical engineering from the University of Pennsylvania in 1959.

In 1948 he joined RCA where he did advanced development work n UHF transmitting systems and some early transistor circuit work. n 1951 he joined the staff of the Moore School of Electrical Engineering the University of Pennsylvania where he has been engaged in research nd is presently an assistant professor of electrical engineering. Among s technical fields of interest are radio interference problems, microwave chniques and components, high-frequency transmission lines, and solid- ate devices.

He has authored a number of technical papers and research reports, nd he holds three patents.

Dr. Schwartz is a senior member of the IRE, a member of the AIEE, e American Association for the Advancement of Science, the American ociety for Engineering Education, *Sigma Xi*, and *Eta Kappa Nu*. A ember of the PGMTT National Administrative Committee, Dr. Schwartz eads the Membership Committee and also serves on the editorial board r the *PGMTT Transactions.*



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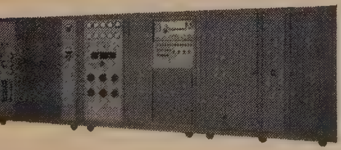
One of these may be the solution for one of your current problems. If not, tell us what your needs are and let us supply information on other examples of our equipment engineering.

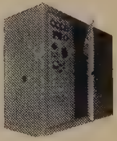
0 KW—MODEL 241T

his equipment, illustrated above, is typically capable of 50-kw c-w output ith 45-db gain in the 300 to 500-mc range, using an Eimac 4KM170,000LA lystron. Pulse capability up to 200 kw can be provided.



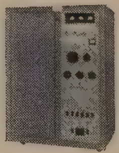
10 KW—MODEL 82T

Considering tubes readily available, this Levinthal transmitter can be supplied with typical gains ranging from 25 to 40 db in frequency bands ranging from 225 to 2400 mc.



2 KW—MODEL 208T

Here, a series of typical klystrons gives a selection of operations with gains from 30 to 50 db over frequency bands including extremes of 385 and 8500 mc.



1 KW—MODEL 74T

A variety of klystrons is available to provide the Model 74T with typical gains from 25 to 60 db and frequency bands ranging from 385 mc to 10.8 kmc.

Levinthal specializes in the production of high-power r-f transmitters and modulators for c-w or pulsed application. There are presently numerous attractive openings in the expanding engineering force at Palo Alto. If you are thinking about a new direction in your career, send us your resume and let us tell you something about the general advantages of working on the San Francisco Peninsula and those applying to Levinthal in particular.

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n giving the talk; it places him in contact with his ers in the field. Secondly, for the small number o bother to listen carefully to the presentation, it es first-hand knowledge of what someone else has done, full six months or more earlier than they could know they waited for publication. And finally the meetings ovide a means for getting to know others of like in- est from whom a great deal can be learned.

But what of the expense? Since many engineers her claim they cannot afford to belong to a technical ciety, or else that they cannot pay the additional pense of a professional group, let us see what can said on this question.

If the individual were a bricklayer instead of an gineer, the chances are high that he would have no oice; he would have to join the union. The same can said of most trades. If he were a businessman he uld find it to his business advantage to belong to tary, Kiwanis, the Chamber of Commerce, or even me exclusive golf club. The physician usually is a mber of the American Medical Association or at st of the County Medical Society; it affects his liveli- od. The lawyer finds the State Bar Association an in pursuing his profession. In a like manner the gineering society affects the engineer's work and elihood. The expense should be viewed as a legiti- te professional expense — the cost of the privilege remaining in the engineering field.

But what of PGMTT? Or for that matter why pro- sional groups at all? The subdivision of the IRE o such units was a post-World War II development t came about because of the mushrooming special- tion` in the radio-electronic-communication field. longer could the "radio" engineer hope to remain ll-versed in all phases of the art. New technical guages were developing in all specialties, and the E recognized that these special groups needed new lets for the exchange of information.

Professional group subdivision actually was only an ex- sion of the philosophy that led to technical societies in first place, and it is interesting to note such subdivision not unique in the IRE. The AIEE, the Society of Com- nication Engineers of Japan, The American Institute of ysics, to name a few — each have a structure within a ucture based upon specialization.

PGMTT, of course, serves microwave engineers. ne was, for a few years following World War II, that prime reference source for microwave engineers s the Radiation Laboratory Series. True, there were ne other isolated works, and occasionally an inter- ng article in the *IRE Proceedings*, but the main ly of reference knowledge was the half-dozen or so propriate volumes of this set. This is no longer case. Not that a profusion of *books* have replaced Radiation Lab Series; rather the *Transactions of MTT* (together with the present journal) have pro- ed the extension needed. Today the microwave engi- r keeps abreast in *his journal* — a work so specialized t computer engineers, transistor experts, and audio rkers scarcely understand a word of it; yet to the rowave worker it is indispensible.

Again the question: "Who should support and con- bute to this periodical and its sponsoring group?" e answer should be clear.

1942: First production waveguide bending.

1943: First development of mandrel bending techniques.

1944: First design of portable bending equipment.

1945: First development of techniques for aluminum brazing microwave components.

1946: First complete study of materials for microwave transmission components.

1951: First development of techniques for deposit of molecular films on resistive elements of high power coaxial microwave attenuators.

1954: First use of one-piece cast aluminum mixers and duplexers.

1957: First use of magnesium castings for antenna systems.

1959: First full-scale production of magnesium RF systems.

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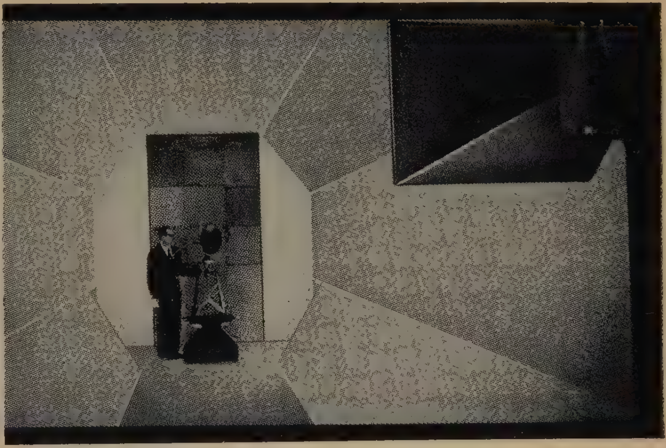

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From the editor

1960 PGMTT SYMPOSIUM

We will be watching the 1960 PGMTT Symposium to be held in San Diego on May 9, 10, 11, with a great deal of interest. This meeting will be held under somewhat different conditions than past PGMTT meetings. Previous meetings of this group have been held in either a large city in and near which much microwave work is taking place; such as, New York, Philadelphia, or Boston, or in an area which is an acknowledged center of microwave activity; such as, Palo Alto.

Although our friends may protest violently, San Diego does not quite fill either category. Of possibly even greater interest is the fact that the entire program will take place in the confines of the del Coronado Hotel, including technical sessions, rump sessions, banquet, and cocktail party. In addition, it is anticipated that most of the people attending the conference will stay at the hotel. This isolation and concentration may well result in a 24-hour per day meeting.

There will undoubtedly be many outside attractions, but this will be the first time in the history of PGMTT symposiums that such complete concentration has been encouraged. The experiment may prove to be an interesting one. The results will undoubtedly affect PGMTT technical meetings for years to come.

If the technical isolation approach is successful, who knows, next year we may go to Hawaii. If it fails, on the other hand, back to New York, Palo Alto, Philadelphia, or Boston. Other groups have made such a transition with great good fortune.

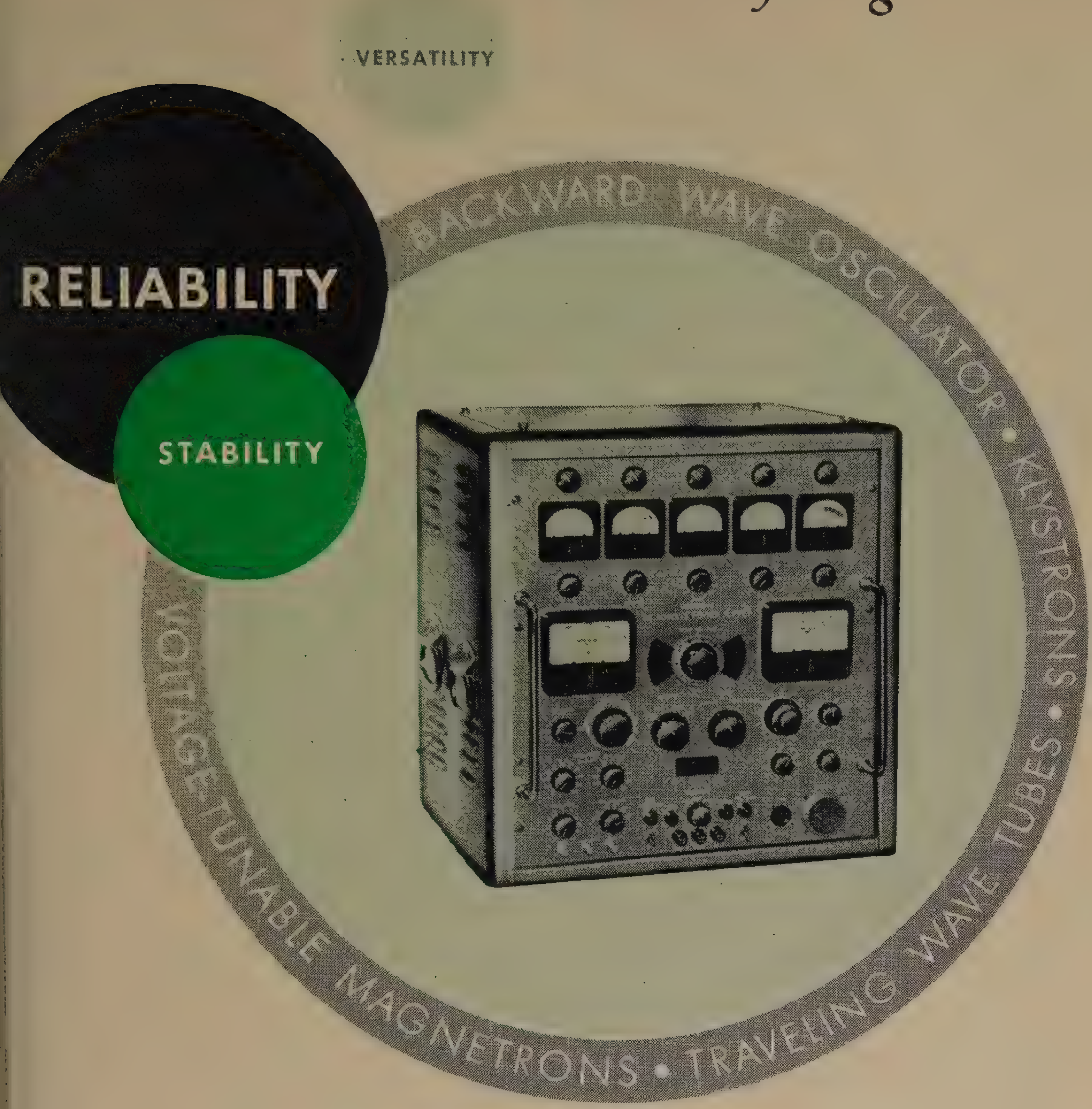
We have heard of technical meetings that have been held in Mexico City, Miami Beach, and other equally exotic locations, with resulting good effects. We hope the same will be true of the 1960 PGMTT Symposium.

One added bit of interest for probable attendees. We have been advised that the del Coronado Hotel was the scene of some of the filming of the motion picture "Some Like It Hot."

We have it on good authority, however, that Marilyn Monroe will not attend the Symposium.

Ted Saad

it has everything...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Manual Operation	Front panel IF gain control
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Sensitivity	100 microvolts
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Standard Models Available

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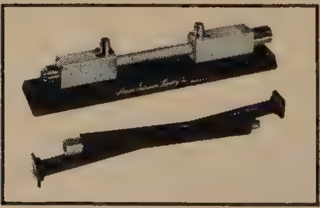

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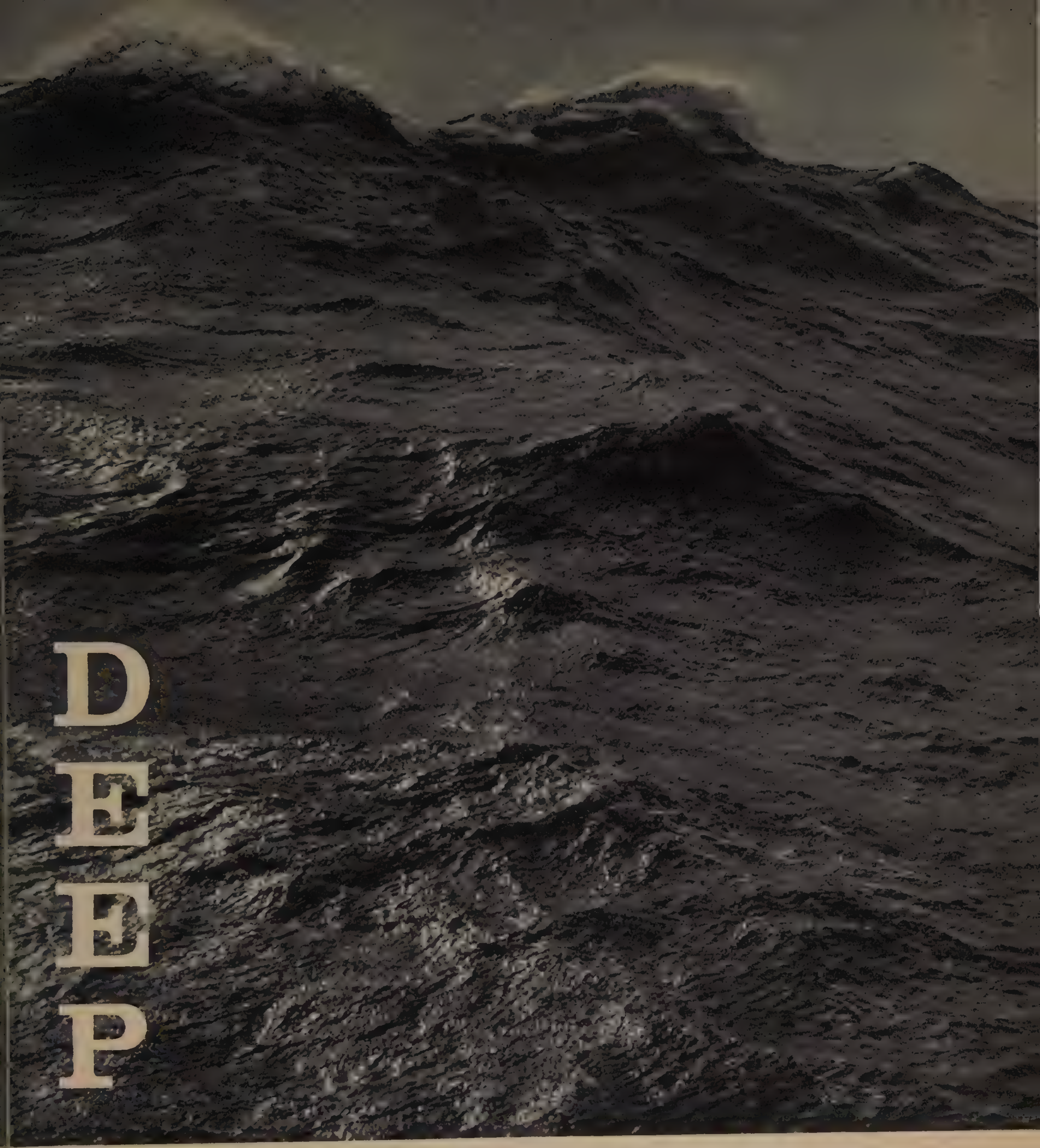

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Because when one magnet parameter goes up another goes down, the true measure of the magnet's quality and usefulness is the ***field-volume-uniformity*** combination and the wide range over which each may be varied. The typical field plot at the right demonstrates that even at a field as high as 20,000 gauss, the Varian V-4012A can accommodate a useful-sized sample within its volume of high-homogeneity field. This 20,000 gauss performance is an achievement that has utilized highly advanced design and shimming techniques. It reflects Varian Associates' unique understanding acquired from years of continuous and productive research in magnet technology.

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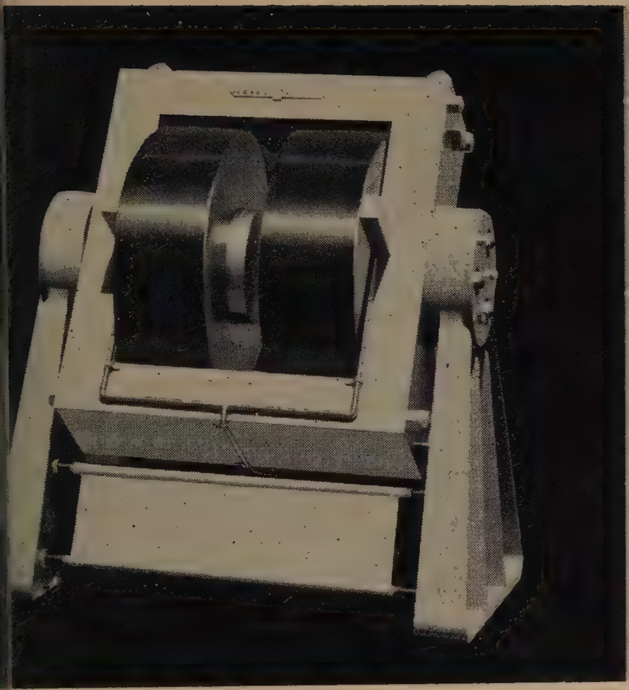

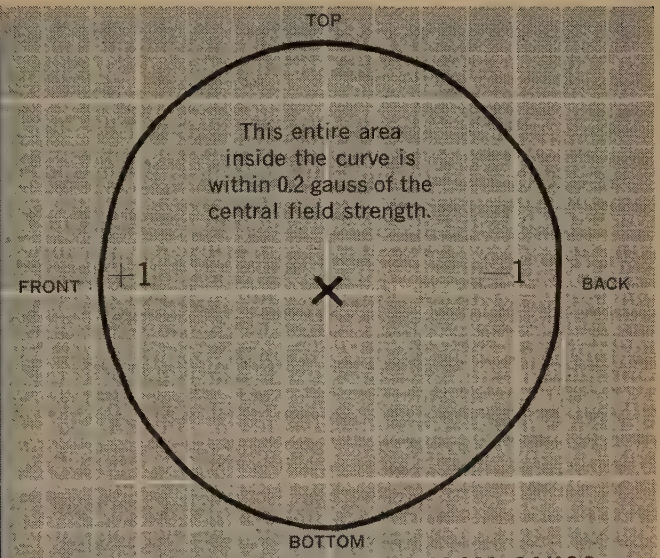
TOP
This entire area inside the curve is within 0.2 gauss of the central field strength.
FRONT
+1
−1
BACK
BOTTOM

HOMOGENEOUS FIELDS AT 20,000 GAUSS The curve is a full-scale field plot in the air gap median plane of a Varian V-4012A magnet operating at 20,000 gauss field strength with tapered pole caps of 6.9 inch face diameter and an air gap of 1.00 inches.

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NEW AND OLD FRONTIERS IN ANTENNAS

ROBERT C. HANSEN

SPACE TECHNOLOGY LABORATORIES, INC.

Los Angeles • California

Associate Editor

the microwave journal

The microwave antenna field is as old as radio; in fact, in the 1890's Hertz and Marconi used parabolic reflectors to beam the r-f energy produced by a spark gap! Frequencies used were 460 and 1200 mc, with the spark gap placed on the focal line. Accomplishments were limited, of course, by the wide spectrum low energy density of the sources. Later coherent sources such as Alexanderson alternators and vacuum tube oscillators came along. These operated at low radio frequencies and produced relatively large power, forcing microwave development to wait until coherent microwave power sources could be produced.

Meanwhile, another frontier was being opened, when in the 1930's Reber used parabolic (dish) antennas for receiving extra-terrestrial noise, thus presaging the field of radio astronomy. He also rediscovered the parabolic antenna after 40 years. Reber used parabolic cylinders, with a resonant feed typically consisting of a dipole in an open ended cavity; highest frequency designed for was 3300 mc. Optical type radiating devices reached a zenith of development at the MIT Radiation Lab during the war years. Applications of geometrical optics and the current distribution method to reflectors culminated in doubly-curved paraboloidal and shaped cylinder reflectors, a major milestone in the antenna art. During the fifties, another important development occurred. This stemmed from the realization by those at the Radiation Lab that optical devices were limited in providing precise control of the secondary features of a radiation pattern and that electronic scanning would some day be required for many applications. These two factors led to extensive development of arrays, particularly waveguide slot arrays, and of electronic scanning principles by a group of former Naval Research Lab and Radiation Lab people then at Hughes Aircraft Company. Results of this work now in use include very low sidelobe arrays, frequency scanned arrays and reflector feeds, ferrite phase shifter scanned arrays, and electronically variable elements.

In the last several years a new frontier has opened that of communications theory applied to antennas Time was when the antenna was simply plugged into the receiver front end. Then came mechanically-steered antennas which required an interconnection between servo drive system, display, and receiver. Next, electronic scanning antennas required, in addition, a complex programmer which controlled both display and drive. The next logical step is to erase the boundary lines between antenna, receiver, programmer, etc. Now the antenna is no longer a two-port device transforming incident waves into signals in a waveguide or coaxial line output. Instead, it is a spatial filter in which data processing or correlation can be performed right in the antenna system. Now the goal is to optimize the transfer function of the antenna system, instead of maximizing antenna gain or minimizing beamwidth. For instance, in a mapping application, the goal is to most faithfully duplicate the object. For communications the goal is maximum data rate consistent with specified error rate. For a scanning search mission, detection ability within a given volume should be optimized All of these are often not consistent with maximum gain.

There are a number of ways of exploiting this new idea. One way is to sample the output of each element of a receiving array and to assemble these outputs in a computer, analog or digital. This allows such sophisticated modes of operation as multiple track-while-scan since typical computer speeds are much greater than the speed with which the data are changing (due to target motion). Conventional electronic scanning, of course uses an analog device consisting of transmission line waveguide plus phaseshifters to connect all the elements which usually means that only one function can be performed at a given time. A second idea is to use frequency bandwidth to obtain augmented performance Several investigators have shown that there is a space

(*Continued on page 20*)

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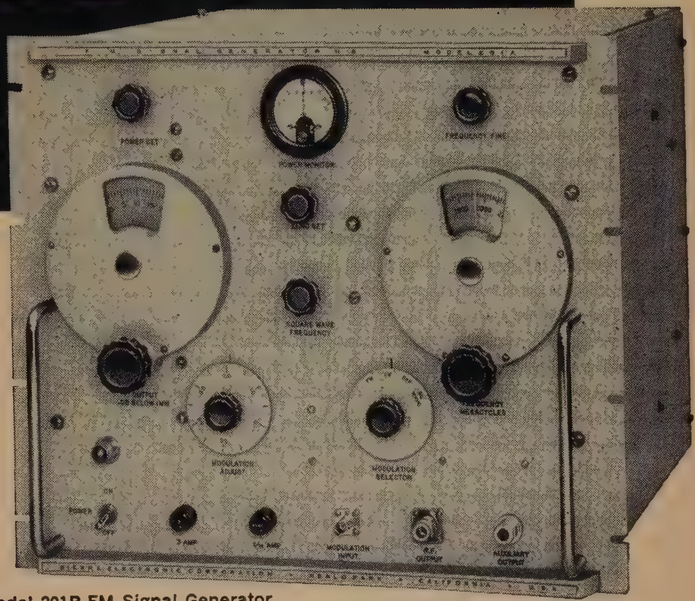

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Superior FM characteristics, 1% deviation linearity. Precisely calibrated output continuously variable 0 dbm to —110 dbm. External modulation (to 500 kc) or CW output. Wide tuning range, vernier, direct reading.

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SPECIFICATIONS

Frequency	
Range:	1300 mc to 2500 mc in one band.
Tuning:	Separate vernier control for small changes in frequency.
Stability:	Drift not over 5 kc per minute.
Dial Accuracy	1%
R.F. Output—Calibrated	
Level:	Continuously variable 0 dbm to −110 dbm.
Output Accuracy:	Within ± 3 db from 0 dbm to −20 dbm, ± 1.5 db from −20 dbm to −60 dbm, ± 1 db from −60 dbm to −90 dbm and ± 3 db from −90 dbm to −110 dbm.
Source Impedance:	50 ohms, VSWR less than 1.6.
R.F. Output—Auxiliary	
Level:	Non-adjustable, 0 dbm to −5 dbm.
Isolation:	Exceeds 30 db.
Source Impedance:	50 ohms, VSWR less than 1.3.
Modulation	
Internal Squarewave AM:	100% AM modulated by internally generated 800-1200 cps squarewave.
External Frequency Modulation:	Deviation linear within 1% to 2 mc, within 2% to 3 mc. Response within 0 to −3 db, 100 cps to 500 kc.
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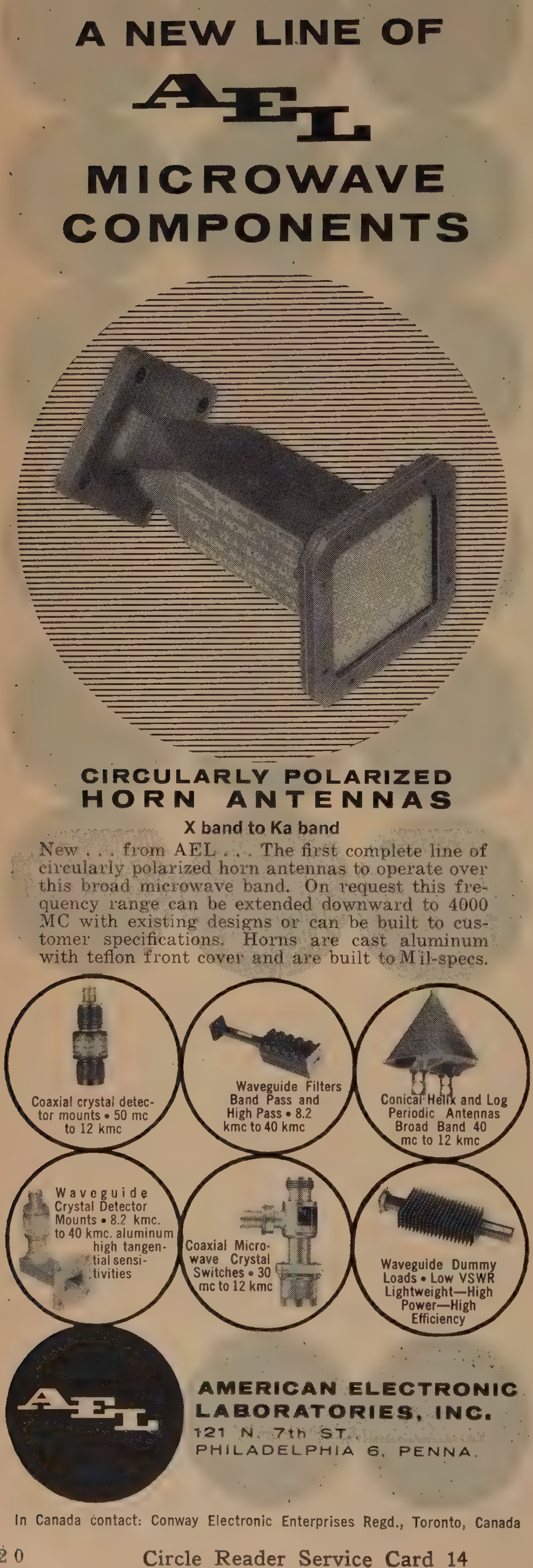

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Antenna Frontiers

(Continued from page 18)

frequency equivalence in which physical size may b exchanged for bandwidth. For example, an array usin a frequency band can produce performance (resolutio and sidelobes) equivalent to a larger array or an arra of more elements, operating at a single frequency. Another way of utilizing space-frequency is to modulat some parameters of the antenna such as size, illumination function. Now each modulation frequency component of the output signal has a specific spatial pattern associated with it. Careful choice of the modulation can produce an antenna system with enhance characteristics or with multiple simultaneous capability e.g., a stack of search beams for such applications a airport surveillance. A trivial example of dual capability is the conical lobing dish antenna where th dc component of modulation gives the sum pattern and the first harmonic (lobing frequency) gives difference or tracking pattern. Yet another scheme i that of time correlating the output of an antenna wit outputs of other antennas, or with itself while scanning This is an application of techniques widely used in signal detection circuits where an integrating filter cross correlates the signal and a construction of what should be like. Advantages include realization of improved resolution. An anti-multipath communication system called RAKE applies statistical correlation techniques not to antennas but to the transmission medium the ionosphere, using a wideband signal with an optimum weighting function (for the ionosphere) applie for each frequency component. One may also appl logical type operations such as switching to a set c antennas. The simplest type of this system is the Mil Cross which gives the resolution of a rectangular aperture the size of the cross. Other examples include sidelobe rejection switching.

Finally, there are a number of studies on how muc information is contained in an arriving wave and ho to extract some of it in an optimum manner. So fa each investigation has concerned a particular facet c integrated antenna systems. What is needed now is unified theory which will embrace all these aspects an present a coherent (no pun intended) picture of th phenomenon.

One may project all of this to the future and envisio a system in which an integrated antenna system used with each element of the antenna having a buil in solid state processor which supplies inputs to a digital computer. The computer provides space and tim correlation and provides a multiplicity of output dat The new packaging techniques, micro-electronics an molecular-electronics, may have appeared just in time permit realization of this type of integrated antenn system. At any rate, this new frontier gives antenn engineers a chance to learn about information theo and systems, and should produce some valuable advances. Pioneers in this field are: E. Wolf, A. Blar LaPierre, R. W. Bickmore, Hans Zucker, W. D. Whit C. J. Drane, L. R. Dausin, R. Price, P. E. Green, E. Hiller, and B. Y. Mills.

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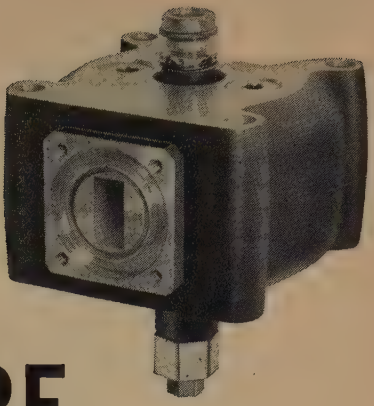

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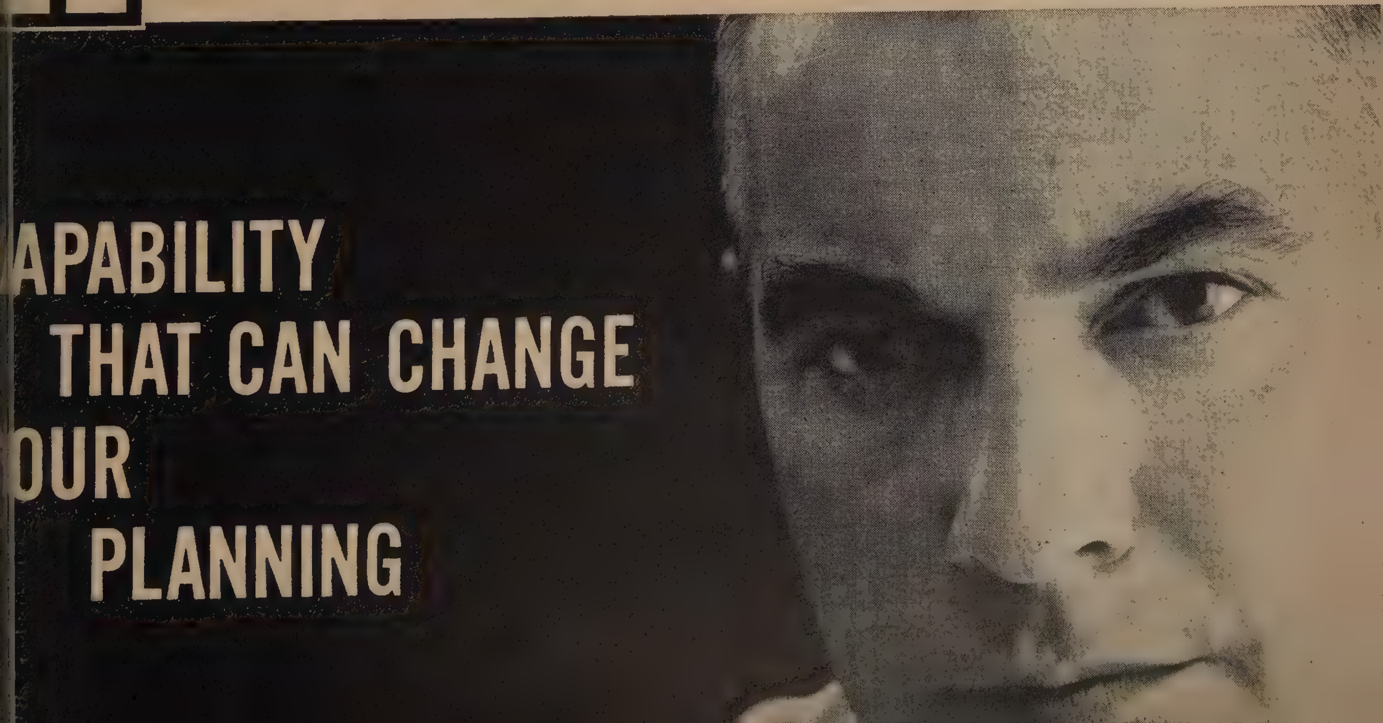

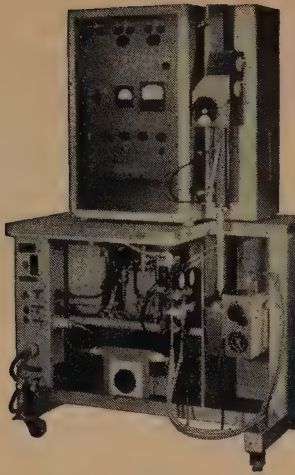

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Industry News

FLIGHT COLLISION AVOIDANCE PANEL

The IRE announces a panel discussion on a subject that ha been before the public attention recently, "Flight Collision Avoidance." The panel is sponsored jointly by the Boston Section PGMIL and PGANE, and will be held on the evening of Ma 5, 1960 at John Hancock Hall, Boston, Mass. Moderator of th panel will be Lt. General Kelsey, (Ret.) Fellow, MIT. Pane members are: Major General J. D. C. Caldara, USAF; Mr. Jame Anast, Director R&D Bureau, FAA; Mr. Jerome Lederer, Dire tor, Guggenheim Flight Safety Foundation.

— *mwj* —

GLOBAL COMMUNICATIONS SYMPOSIUM

IRE also announces the Fourth Global Communications Symposium, co-sponsored by the IRE Professional Group on Communications Systems and the U.S.A. Signal Corps in honor of its one hundredth anniversary. The meeting will be held August 1, 2 and 3, 1960, at the Statler Hilton Hotel, Washington, D.C. A call for papers has been issued, with a deadline for abstracts o May 16, 1960. All papers should be addressed to Mr. Ralph Clark, c/o Office of Director of Defense Research and Engineering Washington 25, D.C.

— *mwj* —

GENERAL RADIO DIRECTORS' MEETING

An announcement from General Radio Company, West Concor Mass. reports that at a meeting of the Board of Directors hel March 3, 1960, Donald B. Sinclair, formerly vice-president an chief engineer, was appointed executive vice-president and technica director. Arthur E. Thiessen, formerly vice-president, was name chairman of the board. Ivan G. Easton was appointed vice-pres dent for engineering, and Harold M. Wilson vice-president f manufacturing.

— *mwj* —

S-F-D LABORATORIES ANNOUNCE EXPANSION

Dr. Joseph A. Saloom, president of S-F-D Laboratories, Unio New Jersey, has announced expansion plans that will add 720 square feet to its existing 10,800 square foot facility. Accordin to Saloom, the expansion is made necessary by increases in th firm's R&D contracts. Employment at S-F-D is also expected t increase from the present 37 people to about 65 within the ne six months. The new building will be ready for occupancy b June of this year.

S-F-D Laboratories, Inc., is a subsidiary of Varian Associates.

— *mwj* —

NEW DIVISION FOR HEWLETT-PACKARD

A new division for engineering and manufacturing microwa instruments, signal generators and waveguide devices has bee formed by the Hewlett-Packard Company, Palo Alto, Californi According to David Packard, president of H-P, Mr. Bruce Whol has been named General Manager of the new division. Dr. Howard Poulter will be Engineering Manager for product developmen and Mr. Gordon Eding has been named Plant Manager.

REPRINTS

Reprints of complete Technical Sections from back numbers of *the microwave journal* are available from the publisher at a cost of 25 cents per back number. Supplies of the following Technical Section reprints are currently out of stock: Vol. 1, No. 1, July/August, 1958; Vol. 1, No. 2, September/October, 1958; Vol. 2, No. 1, January, 1959; Vol. 2, No. 2, February, 1959.

Creative Microwave Technology

Published by MICROWAVE AND POWER TUBE DIVISION, RAYTHEON COMPANY, WALTHAM 54, MASS., Vol. 2, No. 1

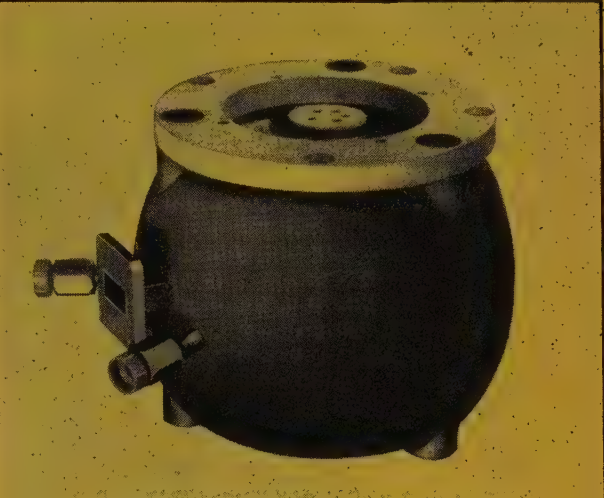
RAYTHEON "M"-TYPE BACKWARD WAVE OSCILLATORS

Electronically tunable at high power levels
for a wide range of microwave applications

re extensive frequency mobility is re-
red, the efficient crossed-field, "M"-
e backward wave oscillator is highly
satile. Introduced more than eight
ars ago, it has been perfected by
theon and is now being economically
s produced. Hobbing of the slow-wave
ucture, a Raytheon-developed tech-
ue, assures precision construction
essary for consistently reproducible
formance from tube to tube.

ical of the "M"-type BWO's available
m Raytheon is the QK-634A, an X-band
e which features all ceramic-and-metal
struction for reliable operation under
reme environmental conditions.

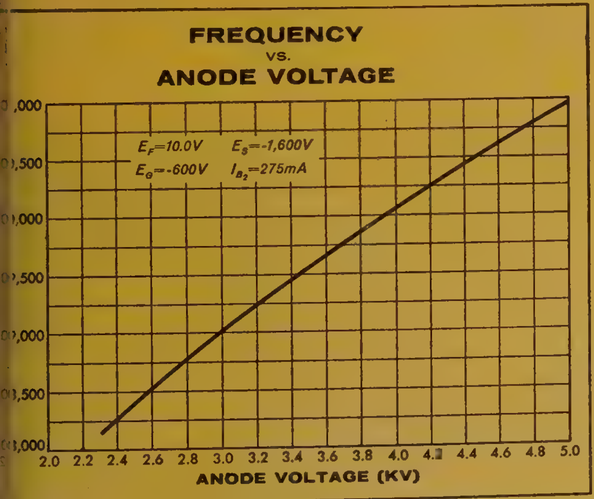
QK-634A has a nominal power output of
to 250 watts and is electronically
able over its entire frequency range.
cise determination of the radiated
ctrum is accomplished by adjusting the
tage applied to either the anode or
sole. Amplitude modulation is also
omplished electronically. Small and
pact, the QK-634A can be mounted in
position.

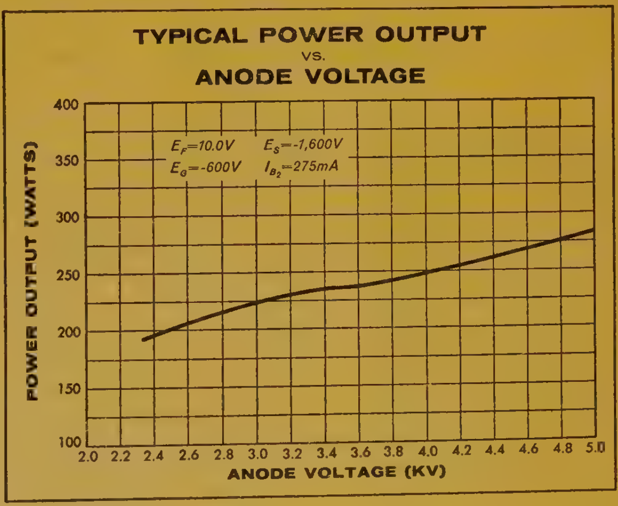


QK-634A Backward Wave Oscillator

Typical Operating Characteristics--QK-634A

Frequency Range	8,150 to 11,000 Mc
Power Output	150 watts (min.) 200 to 250 watts (nom.)
Output Flange	Mates with UG40A/U modified for clearance holes
Tuning Sensitivity	1.0 Mc/V





er unclassified BWO's in this series include the QK-625 and QK-659, which cover the 2,500-4,450 Mc band.

Excellence in Electronics

You can obtain detailed application information and special development services by contacting: Microwave and Power Tube Division, Raytheon Company, Waltham 54, Massachusetts

RAYTHEON

A LEADER IN CREATIVE MICROWAVE TECHNOLOGY

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NEW

THE MOST COMPACT LOW-PASS, HIGH-PASS MICROWAVE FILTERS

Available for Rated Characteristics

Frequency Standards now introduces a standard line of low-pass and high-pass microwave filters, the smallest and lightest available for rated characteristics.

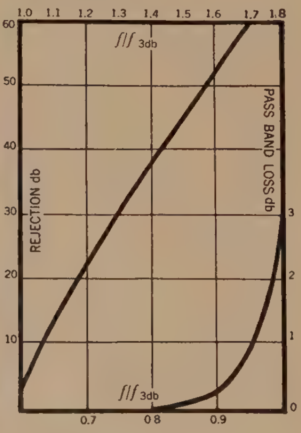
The filters can handle power capacities of up to 2 KW peak. All have a maximum insertion loss of 0.5 db in their pass-band. Input VSWR below the 0.1 db down point for low-pass filters and above it for high-pass filters is held to 1.5:1 or less.

Units are furnished with Type N RF connectors.

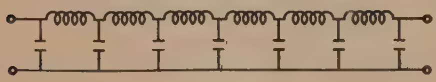
LOW-PASS FILTERS

Standard Low-Pass Filters Available

Model	1 db Down Frequency
FS 5L	500 MC
FS 12L	1200 MC
FS 23L	2300 MC
FS 31L	3100 MC
FS 60L	6000 MC



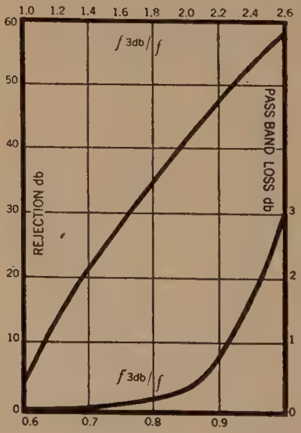
13 ELEMENT NETWORK

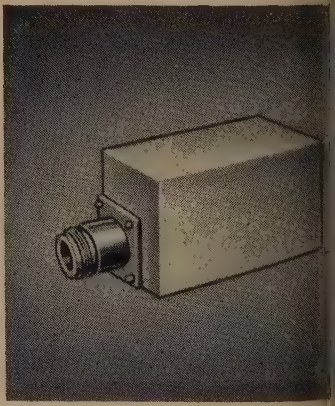


HIGH-PASS FILTERS

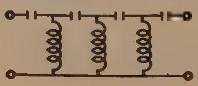
Standard High-Pass Filters Available

Model	1 db Down Frequen
FS 4H	400 MC
FS 9H	900 MC
FS 20H	2000 MC
FS 27H	2700 MC
FS 54H	5400 MC





7 ELEMENT NETWORK

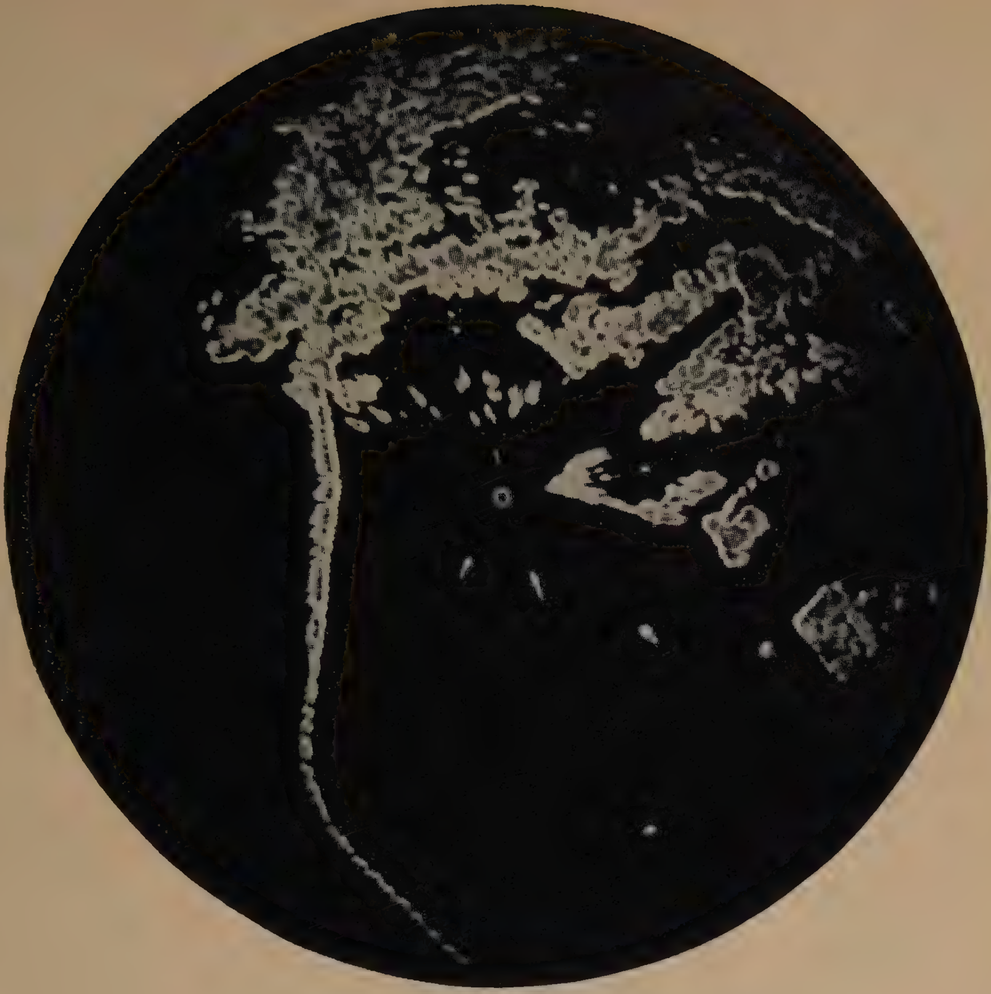


Filters having other 1 db down frequencies, different numbers of elements or other types of RF connectors are available on special request.

Write for Further Information

FREQUENCY STANDARDS

Division of Harvard Industries, Inc.
Box 504, Asbury Park, New Jersey
Phone: PRospect 4-0500
TWX A PK 588



Full Photographic Detail for Ground Mapping with Hughes TONOTRON Storage Tubes

The Hughes TONOTRON* tube presents a complete spectrum of grey shades. **Result:** high-fidelity picture reproduction. The illustration above shows an unretouched photograph of a typical radar display as viewed on a Type 7033 TONOTRON storage tube.

Additional outstanding characteristics of the TONOTRON tube are: high brightness (in excess of 1500 foot-lamberts with full half-tone range), and controllable persistence. The family of TONOTRON tubes is ideally suited for ground mapping, weather radar displays, slow-scan TV, "B" scan radar, oscillography, armament control radar, optical projection systems and miniature radar indicators.

In addition to the Type 7033 TONOTRON tube, Hughes also offers you 21 other storage tubes (including MEMOTRON® tubes and TYPOTRON® tubes) ranging in size from 3 inches to 21 inches—*the world's most complete line of storage tubes!*

For complete technical data and application information, write or wire: HUGHES, Vacuum Tube Products Division, 2020 Short Street, Oceanside, California.

For export information, write: *Hughes International, Culver City, California.*

Creating a new world with ELECTRONICS

HUGHES

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VACUUM TUBE PRODUCTS DIVISION
*TRADEMARK OF HUGHES AIRCRAFT COMPANY

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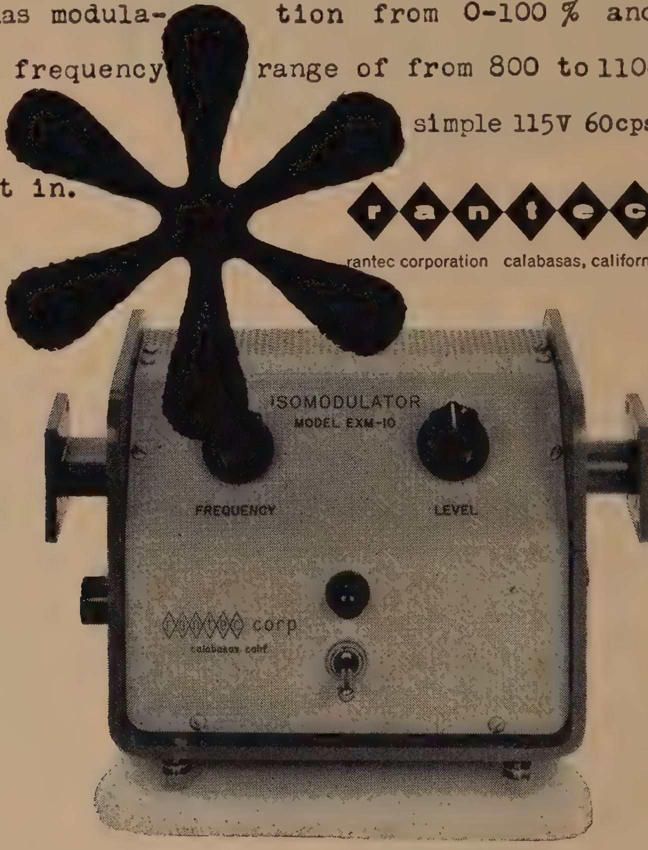
NEW*again from Rantec... a new microwave ferrite device **ISO-MODULATOR** Already termed a "breakthru" in the trade, Rantec's new Iso-Modulator presents an immensely simplified approach for microwave bench work or reflectivity measurements. The Iso-Modulator is a self-contained unit which eliminates the need for repeller modulation of a klystron signal source or grid modulation of a BWO. Double moding, frequency modulation and output power instabilities due to repeller modulation as well as frequency pulling and power fluctuation are eliminated. The Iso-Modulator's frequency range is 8.5 to 11.5 kmc (with other frequencies available), its isolation is 15db min., insertion loss is 1 db max. with full modulation and has modulation from 0-100 % and a modulator frequency range of from 800 to 1100 cps. Input is simple 115V 60cps ..just plug it in.

rantec

rantec corporation calabasas, california



Also from Rantec...antennas, ferrite devices, waveguide components, r-f telemetry components, electronic components and microwave sub-systems

Circle Reader Service Card 20

Letters

To the Editor

Technical Editor
the microwave journal

Dear Sir:

Subject: *Atomic Clock Accuracy*

On page 17 of the December issue o *the microwave journal,* in the article o Dr. Jerrold Zacharias, the following stat ment is made: "It is correct to one pa in 10^{12} or a million million and is th most accurate and stable clock in com mercial production. The National Com pany for which he is a consultant, is pr ducing the clock."

Doesn't this exceed the theoretical lim of accuracy of the Atomichron and do no comparisons of two Atomichrons show di ferences of several parts in 10^{10}?

Yours truly,
Harry R. Meahl
High Frequency Measurements Engineer
General Engineering Laboratory,
General Electric Company

— *mwj* —

• Mr. Meahl's letter was forwarded t Mr. Zacharias for comment. His remark follow. — *Editor*

Technical Editor
the microwave journal
Boston 19, Massachusetts

Dear Sirs:

The statement that Mr. Meahl refers t "It is correct to one part in 10^{12} or million million and is the most accura and stable clock in commercial produ tion," needs some interpretation.

These atomic beam cesium clocks manu factured by the National Company an called Atomichrons are, in fact, the mo accurate and stable clocks in commerci production, and, for that matter, anywher The newer NC 2001 models will agre with each other by unrelated tuneups t about one part in 10^{10}. The electron control system splits the spectral lin width of one part in 10^8 to .01 percen The present model NC 1001 agrees wi each other on independent alignment within a few parts in 10^{10}.

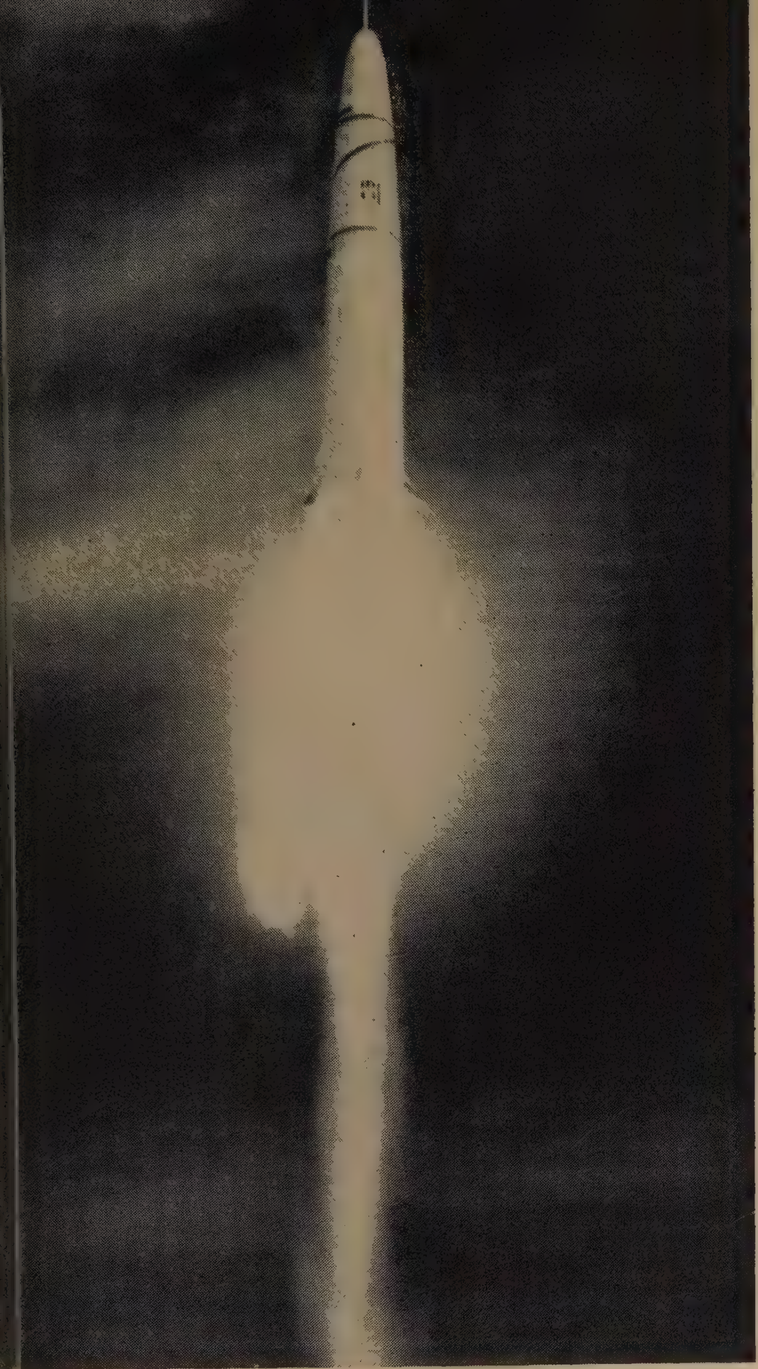
There have been several experimen in which two NC 1001's have been sy chronized over long periods to within part in 10^{11} and in other cases up to fi parts in 10^{13}. These experiments demo strate the fundamental capability of t Atomichron.

I hope this answer is sufficient.

Very truly yours,
Jerrold R. Zachar

— *mwj* —

(*More Letters on page 28*)



EIMAC CERAMIC-METAL REFLEX KLYSTRONS FOR SEVERE ENVIRONMENT APPLICATIONS

In modern airborne and missile systems, reflex klystrons must be capable of maintaining exceptional frequency stability under conditions of severe shock, vibration and acceleration. Eimac's new ruggedized X- and K-Band reflex klystrons achieve this stability through an advanced system of stacked-ceramic construction and integral brazed 'dual-cavity' design.

Ceramic construction permits internal electrodes to be supported on rigid concentric cones and allows the entire vacuum assembly to be furnace-brazed into a single rugged structure. The resonant cavity design consists of a fixed-tuned (and hence rugged) inner cavity closely coupled through a ceramic window to a secondary tunable cavity outside the vacuum envelope. The external cavity is tuned by means of a capacitive slug over a minimum range of 700 megacycles per tube.

This advanced design has resulted in a series of four exceptionally stable reflex klystrons covering the 8500 to 11,500 megacycle range at a typical output power level of 75 milliwatts. At vibration levels of 15 to 20G the peak-to-peak deviation of these tubes is less than 50 kilocycles for any vibrating frequency from 20 to 2000 cycles per second, with the force applied in any plane of the tube. The advantage of this low FM noise level in local oscillator service is obvious. Ceramic construction and the superior tube manufacturing techniques it makes possible permit tube or seal temperatures of 250°C without impairment of operation.

For severe environment microwave applications investigate the advantages of Eimac ceramic-metal reflex klystrons.

Eimac

EITEL-McCULLOUGH, INC.
San Carlos, California

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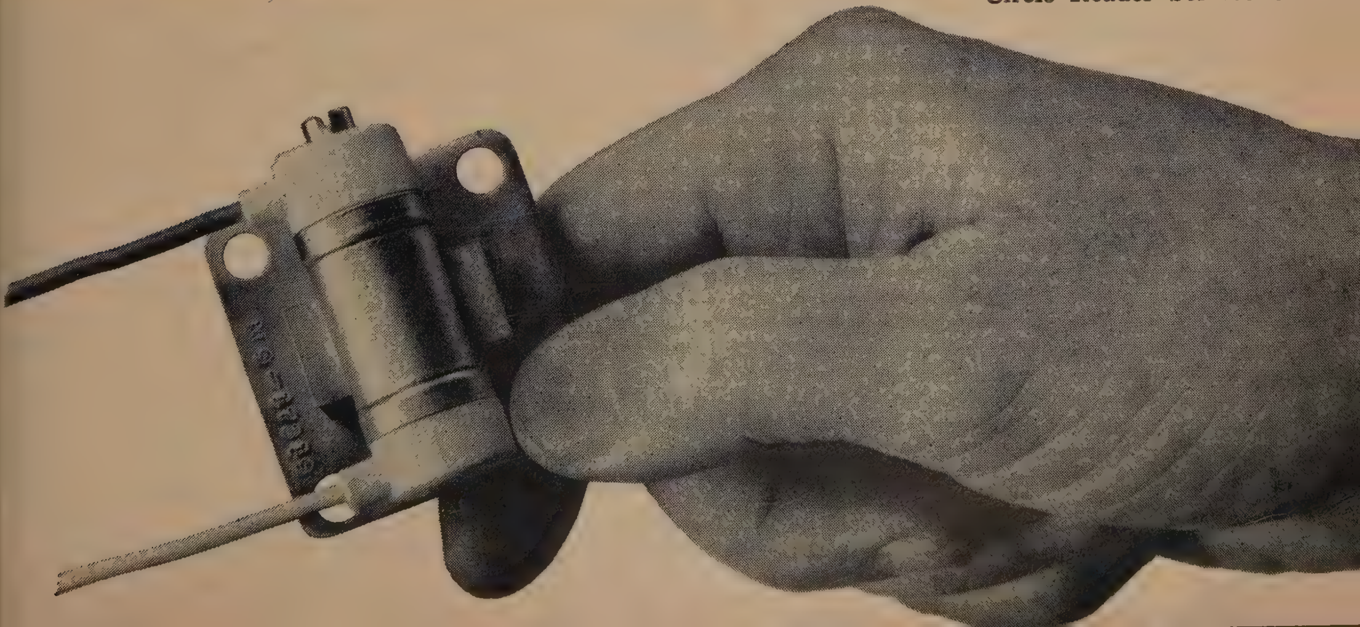

Model 7322/1802

A COMPLETE LINE OF

POWER-THIRSTY THYRATRONS

Model 7620/HY-1

...IN 'PINT-SIZE' PACKAGES

Model 7621/HY-2

EG&G's NEW, COMPLETE LINE OF MINIATURIZED CERAMIC-METAL HYDROGEN THYRATRONS...

Offer the design engineer...

	Model 7322/1802	Model 7620/HY-1	Model 7621/HY-2
• compact modular circuitry			
(length)	5-3/4"	4-5/8"	1-3/4"
(dia.)	3-3/8"	2-5/16"	1-1/5"
• light weight (lbs.)	2.07	0.82	0.13
• max. peak anode voltage	25,000	20,000	8,000
• max. peak anode current (amps)	1,500	500	90
• max. average current (amps)	1.5	0.5	0.1
• wide temperature capability	−55°C to +125°C ambient; 400°C envelope max.		
• long life	unique hydrogen reservoir in all models.		
• rugged dependability	all models pass vigorous shock and vibration tests.		
• fast warm-up	10 min.	5 min.	30 sec.
• high plate dissipation factor	20x10⁹	10x10⁹	1x10⁹

For complete specifications, prices and information on applications exceeding the above ratings, write or call:

Applications Engineering Department...
EDGERTON, GERMESHAUSEN & GRIER, INC.
160 Brookline Ave., Boston 15, Mass., (Tel: COpley 7-9700)
Other Offices: 1622 South "A" St., Las Vegas, Nev. • Bldg. 226, Santa Barbara Airport, Goleta, Calif.

Circle Reader Service Card 22

Letters

(*Continued from page 26*)

Editor,
the microwave journal

Dear Sir:

In connection with my article entitle "Double Ridged Slotted Lines" which appeared in your February issue, we omitte a credit reference to Airtron, Inc. Division of Litton Industries under whos auspices this work was done.

I would also like to point out tha there are a number of other precisio carriage sections made by a company suc as Sage Laboratories and FXR, and number of other probe types such as th FXR probe or the untuned versions o these which can be used for this application.

Cordially yours,
Tore N. Anderso
FXR, Inc.

— *mwj* —

Editor,
the microwave journal
Boston, Massachusetts

Dear Sir:

In reference to the very interesting articl by Mr. E. Hensperger in the Novembe *journal,* I would like to call out a pitfall i the suggested use of W. W. Mumford' Classical Paper on Quarter Wavelengt Coupled Filters.

Ed suggests the use of Equation No. 1 in Mumford's article to find the total filte Q. The problem exists in that the ind vidual cavity loaded Q's as derived b Mumford's Equation No. 11, must eac be multiplied by $(\lambda o/\lambda go)^2$. This operatio then permits the use of Figure 11 in Mun ford's report or the use of Equation No. 3 in order to arrive at the cavity susceptance

We recently calculated six cavity filte in WR-137 Waveguide, using Mr. Mun ford's Classical Paper and achieved an excellent response with band width 200 wider than the calculated value.

Very truly yours,
Robert W. Terry
Airtron, Inc.

— *mwj* —

PAPERS

We wish to emphasize again tha "the journal" is interested in recei ing papers from the industry.

Papers can be addressed to: "the microwave journal," 160 Wa ren St., Boston 19, Mass.

In the West Coast Area please address all papers to: "the microwave journal," Box 113 Palo Alto, California.

— *mwj* —

CHANGE OF ADDRESS

When requesting a change of a dress, please furnish the latest addr at which you received *the microwa journal.* Allow one month for th change to become effective.

MMEDIATE DELIVERY
ROM MICROPHASE CORPORATION

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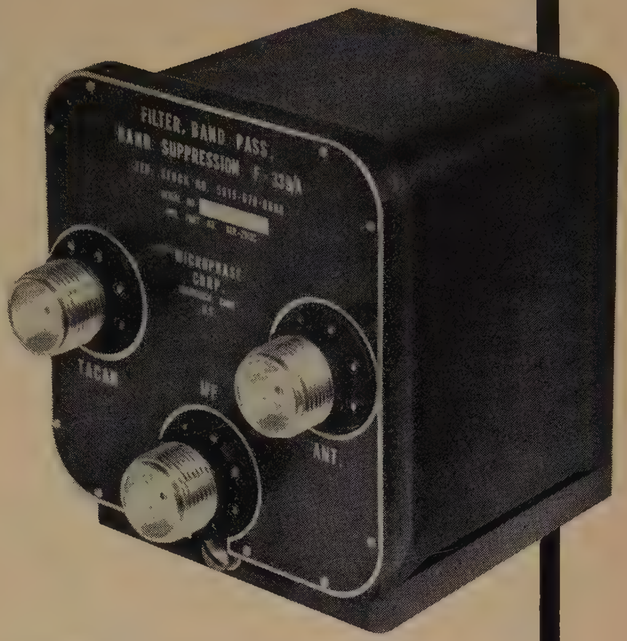

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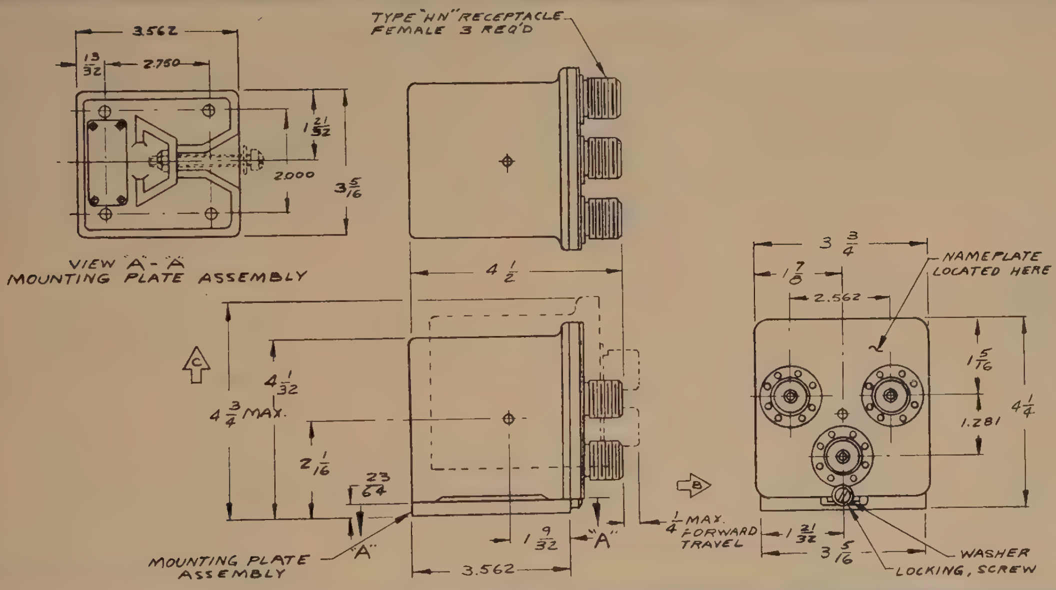

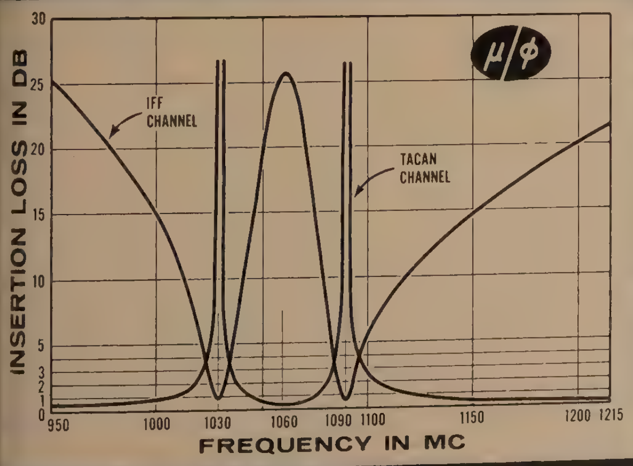

This unique IFF/TACAN multiple-band diplexer was developed by Microphase Corporation for the US Air Force. The unit is fully qualified, and meets the requirements of Specification MIL-F-25880A in its entirety.

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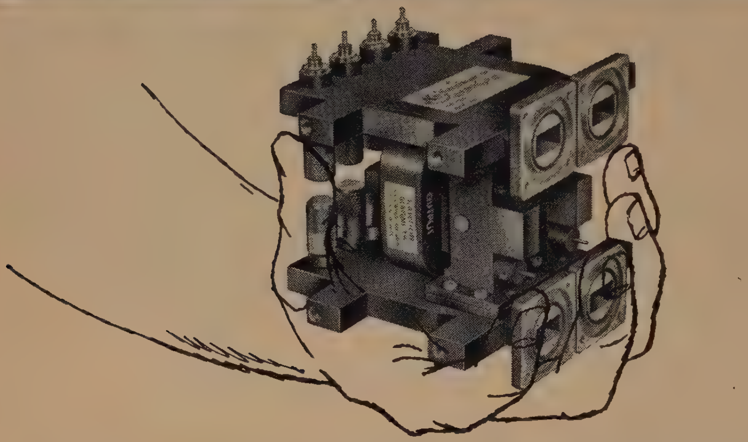

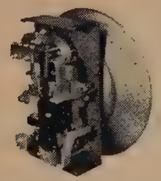

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MICROWAVE SUB-SYSTEMS

Kearfott has the experience and ability to design precision sub-systems to the customer's actual configuration and performance needs. The availability of a wide variety of standard components, coupled with advanced techniques, makes it possible to provide packaged r-f assemblies with a high component density—tailored to precise volumetric specifications. For minimum size and weight in airborne or missile applications—for military system environment—Kearfott will successfully design *your* sub-system—to *your* most exacting requirement.

Mono-Pulse Radar

S-Band Strip-transmission Head

Mixer Duplexer

High Power Mixer Duplexer

Inquiries may be directed to: 14844 Oxnard Street, Van Nuys, California

KEARFOTT DIVISION
GENERAL PRECISION INC.
LITTLE FALLS, NEW JERSEY

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CALL FOR PAPERS

Abstracts of papers to be submitted for the Seventh National Symposium on Reliability and Quality Control, jointly sponsored by the IRE, the AIEE and the ASQC, must be received by May 16, 1960. The Symposium is scheduled for January 9-11, 1961, at the Bellevue-Stratford Hotel, Philadelphia, Pennsylvania.

Ten copies of the abstract, of not more than 800 words, are required. It should include the title of the paper (not to exceed 50 letters, including spaces), the author's name, position and affiliation. In the case of more than one author, please indicate who will present the paper. Ten copies of a biographical sketch (suitable for publication in the Proceedings) of each author must accompany the abstract.

Authors will be notified of acceptance by June 27, 1960. Final papers will be due October 10, 1960. Submit abstracts and biographical sketches to: R. E. Kuehn, IBM Owego, Owego, New York.

— *mwj* —

INVITED PAPERS PROGRAM FOR URSI-IRE SPRING MEETING

The program of invited papers for the Spring meeting of URSI Combined Technical Session has been selected. The meeting will be held May 2 to 5, 1960 at the Sheraton Park Hotel and the National Bureau of Standards, Washington, D.C. The timely program emphasizes problems associated with space. The following invited papers will be given:

"The Transmission Media in Space Communication," by Isadore Katz Applied Physics Laboratory, The Johns Hopkins University.

"The NASA Communications Satellite Program," Leonard Jaffe, Communications Satellite Program, National Aeronautics and Space Administration, Washington, D.C.

"Advanced Research Project Agency's Satellite Communication Systems," Edward A Harriman, ARPA, Washington, D.C.

"Information Techniques in Space Communication," G. H. Mueller, Space Technology Laboratories, Inc., Los Angeles, Calfiornia.

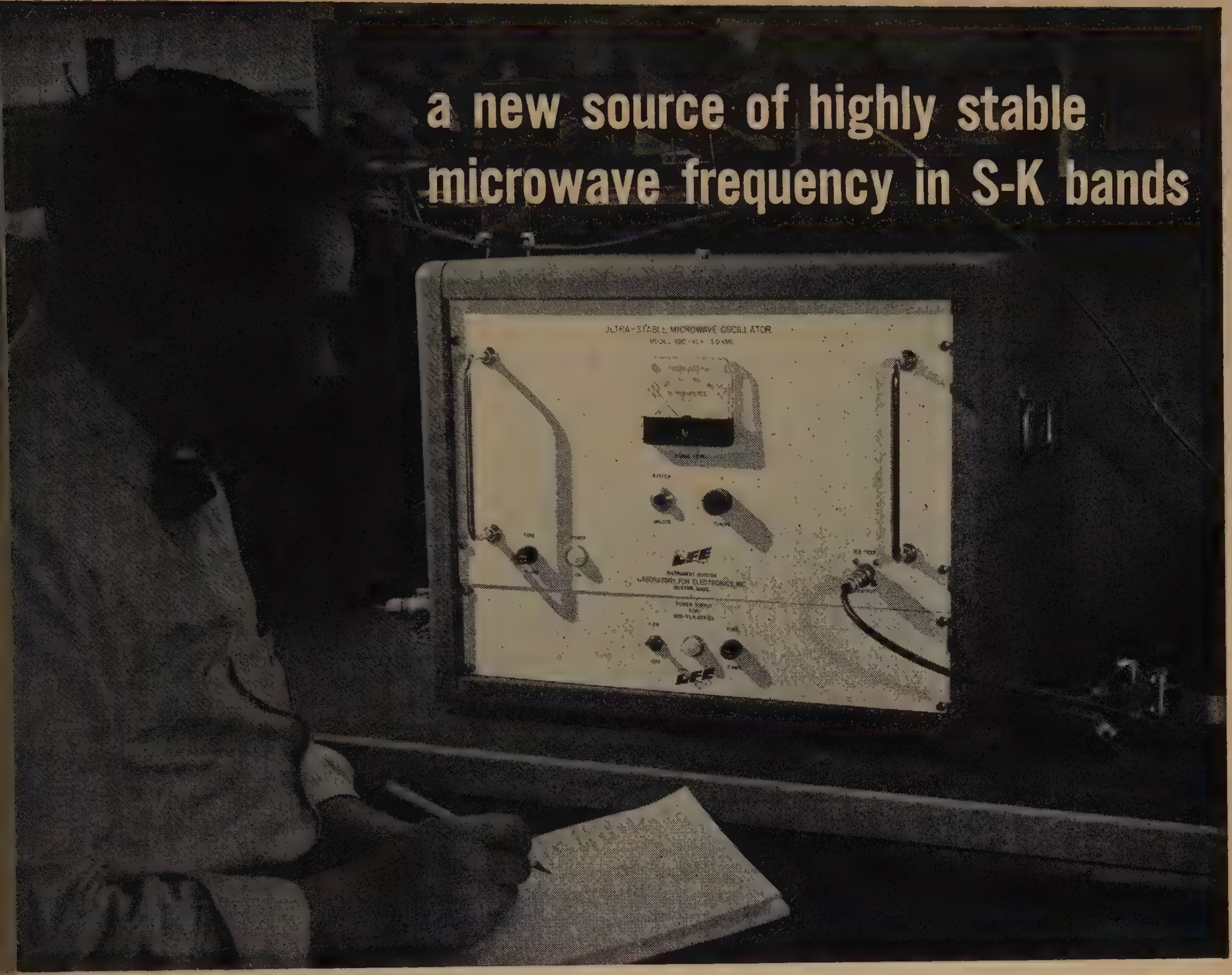
"The Role of Ranging Experiments in Space Exploration," Solomon W. Golomb, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California.

— *mwj* —

NEW FIRM AFFILIATES WITH FXR, INC.

A new electronic component firm, Micromega Corporation, has been formed in Los Angeles, California. The new company's staff of experienced scientists and microwave engineers is headed by M E. Strumwasser and Dr. A. D. Berk President and Executive Vice-Presiden respectively, both formerly associate with the Hughes Aircraft Company.

(*Continued on page 54*)



a new source of highly stable microwave frequency in S-K bands

Introduced at the 1960 IRE Show, LFE's 820-XLK Series offers a new "state-of-the-art" approach to fixed microwave frequency stability.

Utilizing a klystron locked to a quartz crystal through a unique multiplier chain and IF loop, long term stability of 1 part in 10^6 is achieved over a 24 hour period. Incidental FM is reduced to only 1 part in 10^8.

Applications include microwave frequency calibration, parametric amplifier pump sources, radio astronomy, high resolution radar and in research and development programs where low incidental FM and excellent long-term drift characteristics are required.

Write for complete specifications and prices.

SERIES 820-XLK
KLYSTRON
LOCKED OSCILLATORS

Model	For fixed frequence in range of: (see note 1)
820-XLK-S-f*	2500 to 4000 mc
820-XLK-C-f*	4000 to 6500 mc
820-XLK-X-f*	6500 to 12,400 mc
820-XLK-K-f*	12,400 to 18,000 mc

*fixed frequency in KMC/S
Note 1 — Frequency and power determined by Klystron used

LFE
INSTRUMENT DIVISION

LABORATORY FOR ELECTRONICS, INC.
714 BEACON STREET • BOSTON 15, MASSACHUSETTS
WESTERN REGIONAL OFFICE, 211 South Beverly Drive, Beverly Hills, California.

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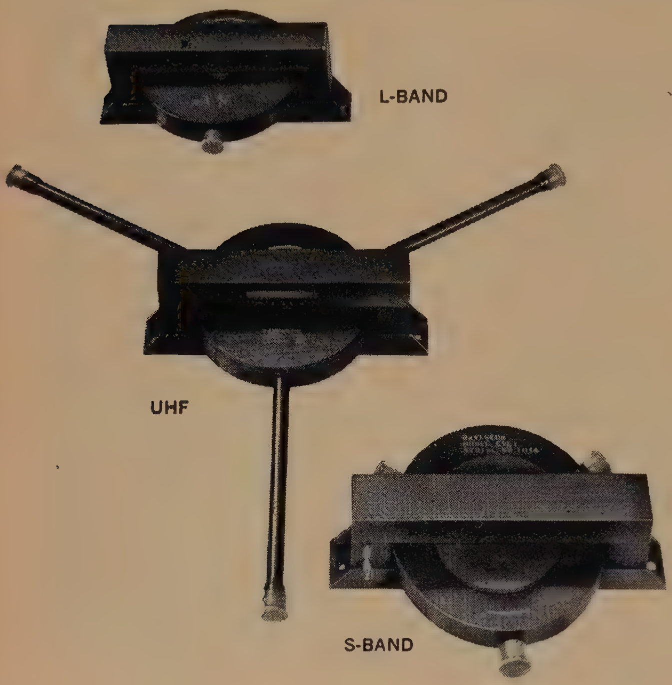
RECENT RAYTHEON DEVELOPMENTS
IN MICROWAVE FERRITE DEVICES

NEW 3-PORT CIRCULATORS FOR MASERS, PARAMETRIC AMPLIFIERS & RADIO ASTRONOMY



TWENTY EIGHT MODELS OF SMALL LOW-LOSS CIRCULATORS FOR L, S, AND UHF BANDS DOWN TO 350 MC

The unusually compact, low-loss, Raytheon circulator design first introduced for L-band applications last summer is now available in *28 standard models.*

The three-port circulators, designed for use with coaxial line, are supplied with fixed permanent magnets or with tunable electromagnets for operation over a broader band. Insertion loss is typically .4 db maximum.† Isolation on all units is 20 db minimum. VSWR is 1.25 maximum. See typical specifications at left.

To learn more about these significant developments or for information about other important Raytheon advances in microwave ferrite devices, please write, stating your particular area of interest, to the address below.

†L&S bands only. UHF insertion loss is typically .5 db.

TYPICAL SPECIFICATIONS

		L & S bands	
	UHF	Tunable units	Fixed units
Frequency range	any freq. from 350-800	any freq. from 800-3000	any freq. from 800-3000
Bandwidth	±5 mc	±50 mc above 1000 mc ±40 mc under 1000 mc	±25 mc above 1000 mc ±20 mc under 1000 mc
Isolation	20 db min. 25 db max.	20 db min. 30 db max.	20 db min. 30 db max.
Insertion loss	.4 db min. .6 db max.	.3 db min. .4 db max.	.3 db min. .4 db max.
VSWR	1.08 min. 1.25 max.	1.08 min. 1.25 max.	1.08 min. 1.25 max.
Power (av.)	5 watts	5 watts	5 watts
Power (peak)	5 kw*	5 kw*	5 kw*
Wt. (max.)	10.0 lbs.	10.0 lbs.	9.0 lbs.
Max. diam.	7½ in. excluding arms	7½ in.	7½ in.

*With type N connector. Powers as high as 90 kw are possible with type HN connector.

RAYTHEON COMPANY
SPECIAL MICROWAVE DEVICES OPERATIONS
WALTHAM 54, MASSACHUSETTS

RAYTHEON *Excellence in Electronics*

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CONTRIBUTORS IN THIS ISSUE

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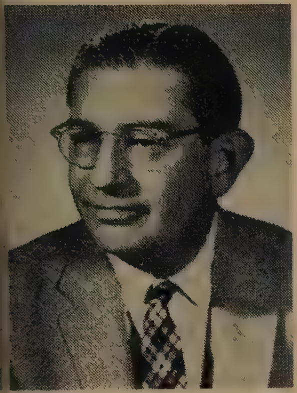

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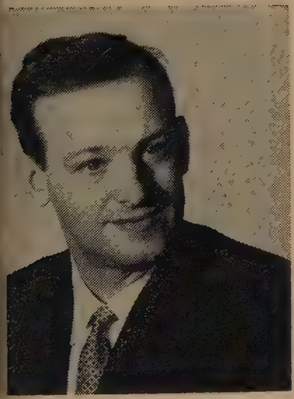

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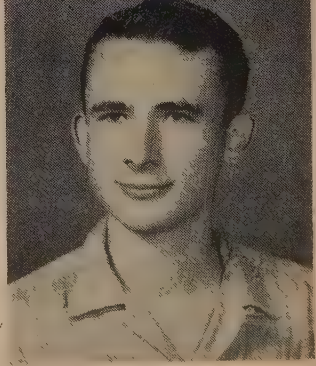

ANS von BAEYER, born in Germany and now a citizen of Canada, received his -college education in Germany, Switzerland and Canada. A Graduate of lumbia University with an AB degree in physics, Von Baeyer did graduate work Germany and is presently attending the University of Miami Graduate School. s work in the electronic field includes his association with the Royal Canadian Force, the Mid-Canada Radar Line, The Time Service of the Dominion Ob- vatory in Canada and with the Andrew Corporation at their Orland Park oratories.

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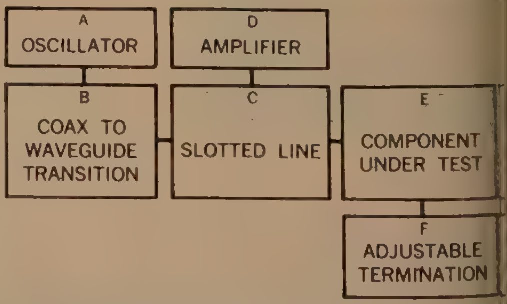

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MICROWAVE ENGINEERING ASPECTS of ELECTRON LINEAR ACCELERATORS

ALFRED E. BARRINGTON
CAMBRIDGE ELECTRON ACCELERATOR
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PART I

story

Although the physical concepts of microwave trans-ssion and cavity resonators were already well under-od at the beginning of World War II, the tremen-us strides which led to the development of micro-ve radar were due largely to the engineering solution the problem of microwave generation. The devices meet this need originated almost simultaneously in o university laboratories, the klystron at Stanford, lifornia, the magnetron at Birmingham, England. e magnetron, because of its mechanical simplicity and mpactness, was eminently suitable as the transmitter high-power microwave pulses urgently demanded large quantities by the Services; although its be-vior and idiosyncrasies have so far defied complete eoretical analysis, it was the prime factor in the suc-s of radar.

However, the demand for high-power microwave rces was not only confined to the military users. ring the decade preceding World War II exciting coveries were made by nuclear physicists with various es of ingenious devices for the acceleration of rged particles. The cascade generator of Cockroft d Walton, the cyclotron of Lawrence and Livingston, n de Graaff's electrostatic generator and Kerst's atron were indispensable tools for the exploration of nucleus. The modest electrical power requirements these machines could all be met by devices well derstood at the time, but the development of the gantic machines envisaged by the physicists to probe o the nature of nuclear forces had to wait for a eak-through in the methods of high power radio-quency generation. Since resonant cavities can be ilt with very low losses it is not difficult to see that usually high voltages can be obtained with only derate consumption of power. In view of the suc-s of the betatron it was apparent, however, that a onant cavity type electron accelerator could compete th this device only if power sources in the megawatt nge were available.

Once again, the magnetron was the answer to the ysicist's problem. And towards the end of World ar II several groups of investigators successfully dem-strated the acceleration of electrons in a novel form waveguide powered by magnetrons. With commercial tubes, electron energies of 10 million volts were obtained. But this was only a modest beginning since the physicists were already discussing experiments with particles having energies of hundreds of millions and even billions of electron volts.

It has required the concerted efforts of chemists, physicists, metallurgists and engineers to meet the challenge presented by these problems and their success has led to a spectacular advance in microwave engineering and technology which will be discussed in greater detail in Part II of this review.

Accelerator Structures

The simplest type of microwave electron accelerator is a cylindrical cavity, oscillating in the TM_{010} mode, which has small holes in the centre of each end plate. A beam of low energy electrons is focused parallel to the axis of the cavity from an external electron gun (Figure 1).

The electrons passing through the cavity during the accelerating half-cycle will gain energy corresponding to the line integral of the electric field along their path. Neglecting transit time, the maximum voltage gained will be $V = \sqrt{PR}$ where P is the power dissipated in the cavity and R is the shunt impedance of the cavity which is defined by this relation.

Let n such cavities be placed end to end with the small holes aligned such that the electrons can pass through (Figure 2), the cavities being excited from a transmission line which has its phase velocity adjusted so as to equal the velocity of the accelerated electrons. Then, if the available power is the same as before and equal portions are distributed among the n cavities, the maximum energy imparted to the electrons will be $V = n\sqrt{\frac{P}{n}R} = \sqrt{nPR}$, which assumes perfect phasing and negligible transit time.

From this elementary picture it is clear that a linear accelerator must either have gaps so small that the particles pass each gap in a shorter time than one-half cycle of the alternating field, or the acceleration must be accomplished by means of an electromagnetic wave with an axial component of electric field and with a phase velocity equal to the electron velocity. The distribution system shown in Figure 2 presents considerable difficulties of construc-

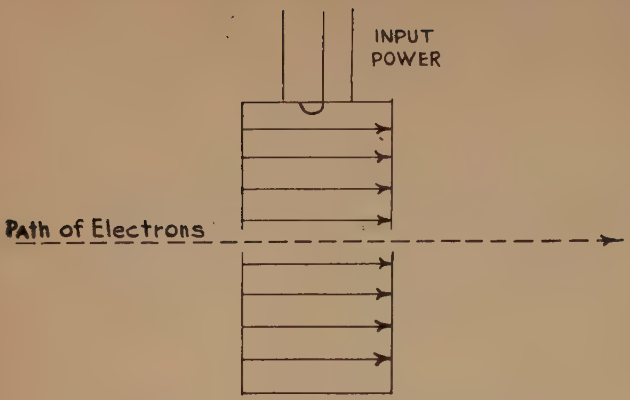

Figure 1 — Single cavity acceleration.

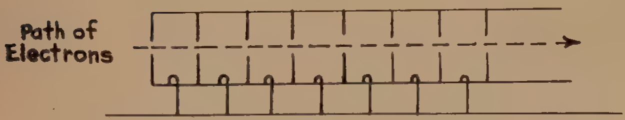

Figure 2 — Multiple cavity acceleration.

tion and in practice it has been found advantageous to choose a structure which serves the dual purpose of accelerator and r-f transmission medium. Some of the possible structures to accomplish this are shown in Figure 3. Of these, (a) is the type on which all important electron accelerators are based at present. Types (b) and (c) are now only of historical interest, but demonstrate the principle very well. Type (b) consists of a coiled rectangular waveguide to form a spiral,[1] type (c) is a folded rectangular waveguide;[2] in both cases a TE mode with a phase velocity greater than that of light is propagated and correct phasing between the beam and the electromagnetic wave is accomplished by proper adjustment of the electrical length between points of interaction.

To appreciate the properties of type (a), we first consider a waveguide of circular cross section excited in the TM_{01} mode (Figure 4). The axial component of electric field of a wave traveling along this guide might be used for the acceleration of electrons, but unfortunately its phase velocity is greater than the velocity of light, which cannot be exceeded by material particles. The phase velocity of this mode of propagation is given by

$$\frac{v_p}{c} = \frac{\lambda_g}{\lambda_o} = \sqrt{\frac{1}{1-\left(\frac{\lambda_o}{\lambda_c}\right)^2}}$$

where λ_o = the free space wavelength,
λ_g = the guide wavelength,
λ_c = the cut-off wavelength,
= 2.61 times the radius of the waveguide.

As λ_o becomes smaller (with increasing frequency), the phase velocity approaches c, the velocity of light. This makes it possible to operate at a frequency much higher than the cut-off frequency, in which case the wave is slowed down sufficiently to interact with an electron of initially high velocity. The electrons will then drift backward slowly on the wavecrest without losing synchronism if the accelerator is not too long. This scheme relies on the fact that electrons approach the velocity of light at relatively low energies (0.5c at 79KV, 0.7c at 200 KV) which can be achieved with comparatively simple electron guns. The disadvantages of operating far from cut-off are that the available r-f power becomes less with increasing frequencies, the energy density and hence the accelerating fields are reduced, and it is not possible to obtain a phase velocity less than c, which may be desirable to improve the acceptance of injected electrons.

There are several methods by means of which it is possible to reduce the phase velocity to less than that of light. The most obvious solution would seem to be filling the guide with a dielectric of high permittivity, ϵ. The phase velocity is then modified according to the formula:

$$\frac{v_p}{c} = \frac{\lambda_g}{\lambda_o} = \sqrt{\frac{1}{\epsilon-\left(\frac{\lambda_o}{\lambda_c}\right)^2}}$$

A small hole can be cut through the centre of the dielectric without affecting v_p greatly, through which the electron beam can pass. Among the disadvantages of the dielectric loaded accelerator are:

(a) the limitation of the peak electric field by dielectric breakdown,

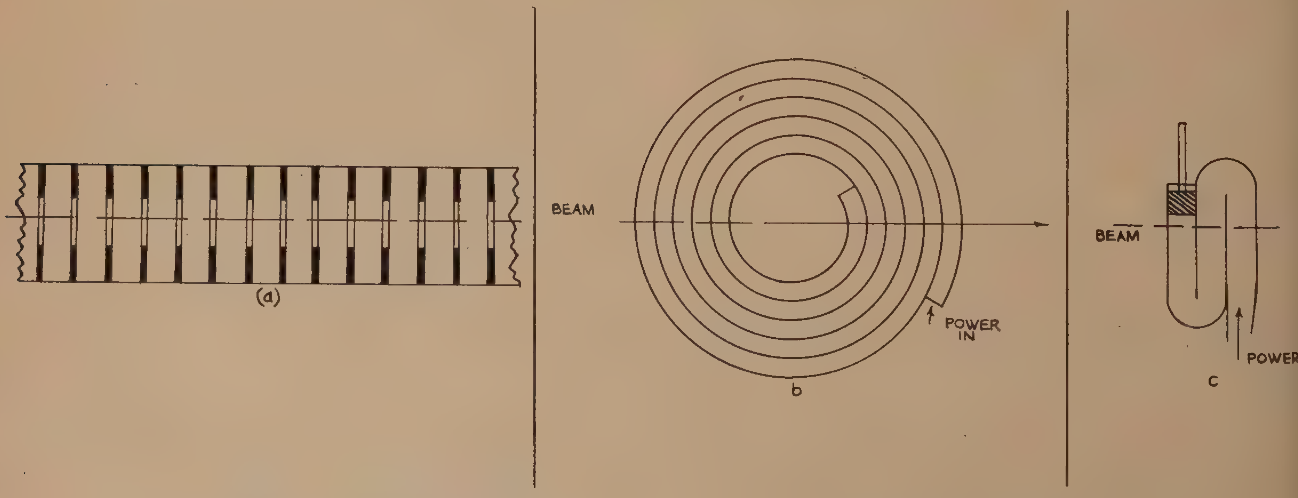

Figure 3 — Linear accelerator structures
(b) spiralled waveguide

(a) iris loaded waveguide
(c) folded waveguide

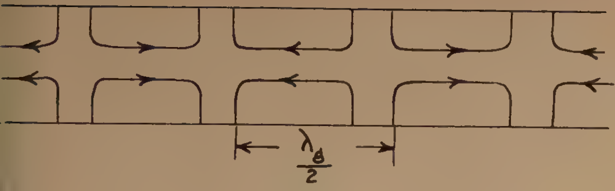

Figure 4 — TM_{01} mode in circular waveguide.

(b) any electrons escaping from the beam constitute a charge which tends to cut off the further flow of electrons,

(c) dielectric losses and difficulty of heat dissipation in the dielectric.

A compromise solution consists of dielectric loading ith artificial anisotropy.[3, 4] In brief, the method involves lamination of the dielectric by means of a large number separate dielectric discs. The theory as proposed in- ally required the disc thickness to be small compared ith the free space wavelength in the dielectric and the stance between the discs to be small compared with e wavelength in the guide. If these conditions are tisfied, such a structure has the properties of an aniso- opic dielectric with a considerably smaller permittivity the axial than in the radial direction. By modifying e dielectric-loaded waveguide in this manner, a con- derable reduction of the total losses and a corresponding crease in the shunt impedance of the system is obtained. e shunt impedance of the dielectric-disc loaded wave- ide is much higher than that of the all-metal system scribed below.

In order to appreciate the most recent work on dielec- c-loaded accelerator structures, it is necessary to consider e properties of the all-metal disc-loaded waveguide nich historically was the first slow-wave structure to be ed in a traveling-wave linear electron accelerator (Fig- e 3a). When this structure is excited with r-f power, ie observes that as the exciting frequency is varied, each ave mode inside the guide consists of an infinite number wave components with different phase velocities which ay be greater or less than the velocity of light. These mponents are required to satisfy the boundary condi- ns imposed by the addition of loading discs. The para- eters of the structure can be obtained from Floquet's eorem which states[5]: in a given mode of oscillation, at given frequency, the wave function (i.e. the electric d magnetic field) is multiplied by a given complex nstant when we move down the structure by one period. ie most general expression of a wave function $f(r, \theta, z)$ thus $f(r, \theta, z) = F(r, \theta, z)e_j{}^{(\omega t - kz)}$, where F is a riodic function in z and k is a complex constant. Since is periodic it can be resolved into Fourier components, d if the period is equal to d, $f(r, \theta, z)$ is composed wave components of the form

$$e_j[\omega t - (k + 2\pi n/d)z]$$

The disc loading can be adjusted until one component traveling at the desired phase velocity. If this compo- nt is the one whose velocity is closest to the phase ve- city in the unloaded guide, it will contain the largest are of the total r-f energy. The r-f energy in the other ive components (space harmonics) does not contribute the useful acceleration of electrons.

In order to demonstrate the properties of periodic trans- ission systems, a useful starting point is the behavior the uniform lossless waveguide.

The relation between propagation constant β and frequency (in terms of ω/c) of this configuration as derived from a solution of Maxwell's equations is: $\beta^2 = \left(\frac{\omega}{c}\right)^2 - \beta_c^2$, where β_c is the cut-off propagation constant. This hyperbola is plotted in Figure 5. From the definitions of group velocity, $(d\omega/d\beta)$, and phase velocity, (ω/β), one finds that a straight line drawn from the origin to any point on the curve has a slope equal to v_p/c and the slope of the curve at any point is v_g/c. The hyperbola lies entirely above the 45° line, so that the phase velocity is always greater than c, but its slope and hence the group velocity is always less than c. It is seen also that above the cut-off frequency corresponding to β_c, propagation is possible in either direction, with positive or negative β.

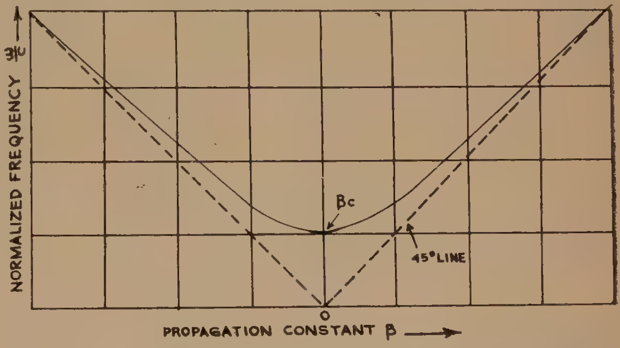

Figure 5 — $\frac{\omega}{c}$ — β diagram for lossless uniform waveguide

Slater[5] has shown that a periodically loaded waveguide behaves as a band-pass filter, having, in general, infinitely many passbands and stopbands associated with each mode type. At each obstacle, there is transmission and reflection of r-f energy. An observer stationed at a fixed point in the plane of one of the discs would find that there are certain frequencies for which the one-way phase shift between discs in the unperturbed guide is $n\pi$, where n is any integer. These frequencies constitute the stop bands. At other frequencies the accumulated reflections add up to zero and transmission occurs. These frequencies con-

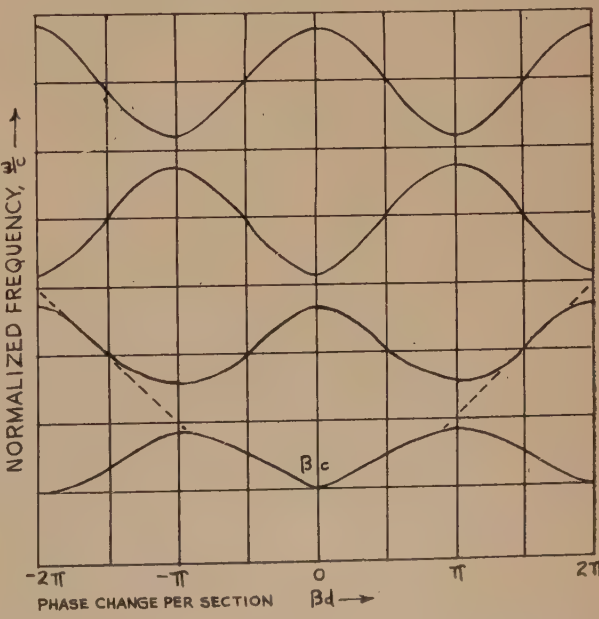

Figure 6 — $\frac{\omega}{c}$ — βd diagram for waveguide with periodic obstacles a distance d apart (dashed line is diagram for guide without obstacles).

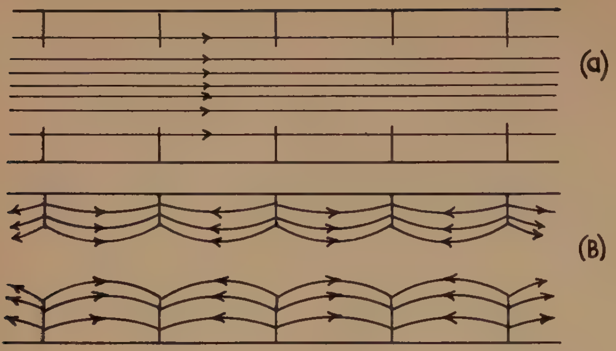

Figure 7 — Electric field configuration in disc loaded waveguide at (a) the low frequency cut-off and (b) the high frequency cut-off of the lowest pass band.

stitute the pass bands. Figure 6 shows a portion of the $\frac{\omega}{c} - \beta$ diagram for a periodically loaded waveguide. The dashed line represents the $\frac{\omega}{c} - \beta$ relation for the waveguide before loading. In any passband there is an infinite number of values of βd differing by 2π for any given frequency. These correspond to the Fourier components or space harmonics referred to earlier. Figure 7a shows the electric field pattern at the cut-off of the lowest passband. At the low-frequency cut-off the field pattern is that of the TM_{01}-mode in uniform guide if the discs are very thin. At the high-frequency cut-off, the field reverses from section to section, and the cut-off occurs when the distance between discs is about one quarter of a free-space wavelength (Figure 7b). As the hole size in the discs is decreased, the $\frac{\omega}{c} - \beta$ diagram changes as shown in Figure 8. In the limit, there is no coupling hole at all, and the structure becomes a series of discrete cavities for which the $\frac{\omega}{c} - \beta$ diagram is a horizontal straight line, which implies that any phase shift between sections is possible at the cavity resonant frequency.

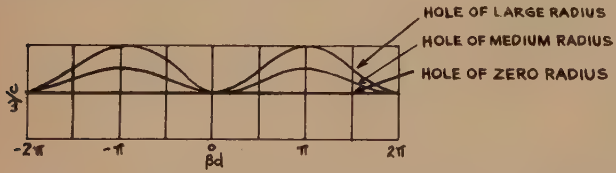

Figure 8 — Effect of hole radius on $\frac{\omega}{c} - \beta d$ diagram.

As in the case of the unloaded waveguide, v_g/c is given by $d\omega/d\beta$, which is the same for all the space harmonics at any one frequency and is proportional to the slope of the tangent to the curve. The phase velocity, v_p, given by ω/β, is proportional to the slope of the radius vector from the origin to the operating point on the curve.

From the nature of the transmission medium, it is possible to construct linear accelerators either as standing wave[6] or traveling wave[7] devices. If the structure is terminated after a finite number of diaphragms so that the energy is totally reflected, a standing wave is set up. The guide acts like a resonant cavity for this frequency, with the diaphragms located at the nodes of the standing wave pattern (Figure 9a). In the traveling wave case, the wave is absorbed in a reflectionless termination after passing through the accelerator, or else the accelerator is of such length that the power reflected from the end arrives back at the power source at the end of the r-f pulse so that the impedance seen by the source is not affected by the reflected wave. Traveling wave accelerators usually operate in the $\pi/2$-mode, with the disc spacings one-quarter of a guide wavelength (Figure 9b); the designation of the mode of operation refers to the phase shift of the accelerating electric field component between successive pairs of obstacles.

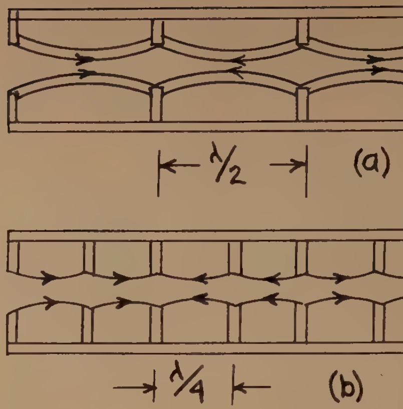

Figure 9 — (a) π-mode in disc-loaded standing wave structure. (b) $\pi/2$-mode in disc-loaded traveling wave structure.

The structure of a traveling wave accelerator must be chosen so that excessive power is not wasted at its output end. For a single feed accelerator of length l, the optimum acceleration is obtained[8] when:

$$l_o \cong 0.403 l,$$

where $l_o = \frac{v_g Q}{\omega}$ (this is termed the attenuation length, i.e. the distance in which the energy of the wave falls to 1/e of its initial value), v_g is the group velocity, Q is the quality factor of the accelerator cavities as resonators and ω the angular frequency of the r-f energy.

In deciding the respective merits of the two types of linear accelerators, one finds that the backward wave in the standing wave accelerator does not contribute to the useful acceleration of electrons. A traveling wave machine should therefore theoretically produce $\sqrt{2}$ times the electron energy obtainable with the standing wave type for the same input power. However, even with optimum design parameters some power is effectively lost at the end of the traveling wave accelerator and, moreover, the standing wave machine has a higher Q and a higher shun impedance due to the reduced surface area of the cav ities resulting from the smaller number of loading discs In practice, the traveling wave machine is found to pro duce electron energies 5-10 percent higher for the same input power than its standing wave counterpart. Th efficiency of the traveling wave system can be further improved by means of an external feedback bridge[9] fo r-f power, which is added to the power from the r-f source and is fed into the accelerator again at the inpu end. The principle is shown in Figure 10. A waveguid is matched to the output of the accelerator guide and le back to a bridge, which has two functions: first, to add the power fed back to the output of the r-f source, sec ondly, to provide full matching for the r-f source, n

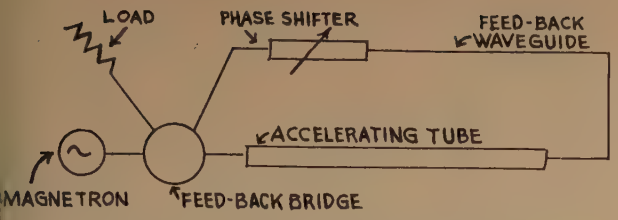

Figure 10 — External feed-back system.

ly under steady-state conditions, but also throughout e build-up time. This is achieved by means of a fourth m with a matching load, which dissipates power only ring the build-up time. The performance of this sys- m is measured in terms of a feed-back ratio, r, which defined as the ratio between r-f power fed back through e bridge and r-f power supplied from the r-f source. is can be written as $r = (S_1 - P)/P$ where S_1 is the wer flux at the accelerator input and P the power de- ered by the r-f source.

In practice, r cannot differ very greatly from unity, ce otherwise great difficulties in the construction of e feed-back bridge arise. However, such a feed-back stem offers a traveling wave accelerator most of the ecial advantages of a standing wave system without loss flexibility. For example, in a standing wave system the celerator length may be very critical whereas the feed ck system can be freely adjusted by a phase shifter in e feed back guide, and length will no longer be such critical factor.

At this point it may be appropriate to comment on a cent investigation[10] into the properties of accelerator uctures loaded with titanium dioxide discs, operating, like the earlier traveling wave systems with artificial electric anisotropy, as resonant structures. If reflecting d walls are placed at points midway between loading stacles so as to form a waveguide containing n sections, esonance is possible when the total phase change in a ogressive wave is an integral multiple of π. If m is an eger, then for resonance, $n\phi = m\pi$ where ϕ is the ase change per section. Thus, in general, there are $+ 1$ values of ϕ which give resonances between o and π, and 2π etc. The $n + 1$ resonant modes in the first pass nd are shown in Figure 11 for a ten-section cavity. It n be seen that the frequency separation between jacent modes is a minimum at the ends of the pass nds where the group velocity falls to zero. The mode paration will obviously also decrease as the number of ctions increases.

Several workers[11] have noticed that there is an advantage operating a resonant linear accelerator in the π-mode, ce the amplitude of the wave which couples with the ectrons to be accelerated suddenly increases when the mode is reached. The accelerator can be operated in is mode only if it is relatively short, so that the adjacent odes are sufficiently far away to present no difficulty in e feeding of power to the structure. To make the best e of the available power sources, the cavity should be long as possible,[12] and it is found in practice that e limit to the possible length in π-mode operation in esent accelerators is set by the mode separation.[13] For is reason some workers[14] have preferred to operate a sonant accelerator in the region of the $\pi/2$-mode where e frequency separation between modes is a maximum. s mentioned previously, $\pi/2$-mode operation involves e use of twice as many loading obstacles as the π-mode for a given cavity length and consequently some of the advantage in mode separation is reduced by increased surface losses. In addition to the accelerating efficiency of the π-mode, it has other, though less important advantages. Fewer loading obstacles are required, leading to a simplification in a manufacture. The large spacing between obstacles tends to reduce the multipactor effect sometimes found in accelerators,[15] by making half-cycle transit-time multipactoring impossible for fields of the order of magnitude found in accelerators.

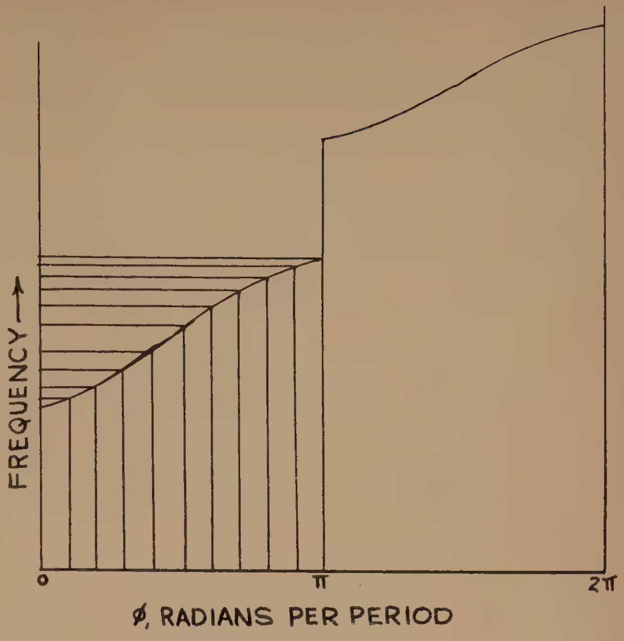

Figure 11 — Typical dispersion curve for a periodically loaded ten-section structure.
(note small frequency difference between π-mode and its nearest neighbor)

It is clear that if by some means the loading obstacles could be made reflectionless at the π-mode frequency, there can be no build-up of a reflected wave, and it should thus be possible for a traveling wave of finite group velocity and a phase velocity of less than c to be propagated. Under such a condition there is no stop-band at the point $\phi = \pi$, and a guide behaves like a confluent bandpass filter of electrical circuit-theory.[16]

For a uniform waveguide propagating a single mode, it is well known that the characteristic wave impedances are given by

$Z_0 = 1/\epsilon\sqrt{\mu_0/\epsilon_0}\sqrt{\epsilon - (f_c/f)^2}$ for a Transverse Magnetic mode,

and $Z_0 = \sqrt{\mu_0/\epsilon_0}/\sqrt{\epsilon - (f_o/f)^2}$ for a Transverse Electric mode,

where ϵ is the relative dielectric constant of the medium filling the guide, μ_0, ϵ_0 are the permeability and permittivity, respectively, of free space, and f_c is the cut-off frequency in empty guide. It is obvious that for a transverse electric mode in a given waveguide, Z_0 must always be greater when ϵ is unity than when ϵ is greater than unity. Thus for this mode it is not possible to achieve an impedance match between air-filled and dielectric-filled regions of a waveguide. However, for a transverse magnetic mode, this is not the case, and at a frequency given by

$$f_m = f_c\sqrt{\frac{1+\epsilon}{\epsilon}},$$

the characteristic impedance of the two regions are equal. This condition was first noticed by Lamont[17] and was used by Barrington and Hyman[18] for the development of a non-resonant TM waveguide window.

Dispersion curves for waveguides loaded with solid dielectric discs show that, for this matched condition, confluent characteristics are possible and experimental confirmation of this has been obtained (Figure 12). Walker and West[10] also evolved an elegant method to achieve matching with discs having a concentric circular hole which is described in their paper.

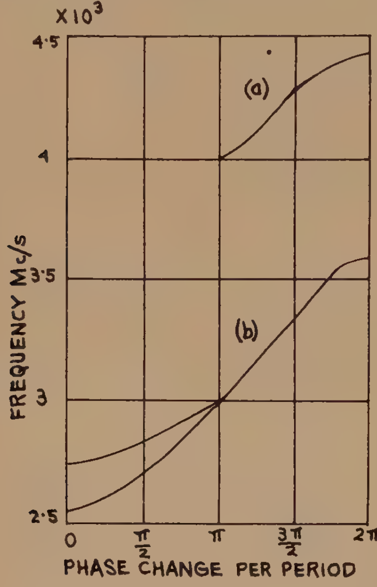

Figure 12 — Dispersion curves for waveguides loaded with dielectric discs, (a) with unmatched discs: (b) with matched discs.

If it is desired to operate an accelerator at frequencies higher than 3000 Mc/s the losses of a dielectric loaded structure become substantially less than those of a metal loaded guide.[19] This may have important consequences in accelerators for the formation of tightly bunched beams as may be required in experiments for the generation of millimeter waves. Walker and Lewis[20] have pointed out that by glazing dielectric discs of titanium dioxide dielectric with a lead-borate enamel, they were able to arrest the deterioration of the dielectric surfaces noticed by other workers[4] at field strengths of 10^4V/cm which is thought to be due to a reduction of the titanium dioxide to a lower semi-conducting oxide which occurs readily in the presence of vacuum pump-oil vapor. They were able to operate with no difficulty at an electric intensity of 3×10^5V/cm which seems to be higher than that used in any machine in operation at present.

Conclusion

The physical situation discussed in the foregoing section is an essential feature of all slow-wave structures and occurs in many devices familiar to microwave engineers, such as magnetrons and traveling-wave tubes. It turns out to be a particular case of wave propagation in periodic structures, many examples of which are met in such diverse branches of theoretical physics as the vibrations of weighted strings or the propagation of X-rays in a crystal lattice. For a more detailed study of the problem which is beyond the scope of this review, the reader is referred to the list of general references.

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END OF PART I

Editor's Note: Part II of Dr. Barrington's paper will appea in the June issue.

MICROWAVE RADIOMETRY

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he author learned with regret, on the very day when the manuscript of this paper was released for publication, that Dr.). O. McCoy died in Cedar Rapids, Iowa, on February 3, 1960. Dr. McCoy was the principal author of Collins Radio esearch Report No. 102, which is used as reference No. 1 in this paper. He was responsible for the activities of the group t the Collins Radio Company Research Division, which, starting in the year 1947, did the pioneering work on radio sexnts. The author has relied heavily on CRR-102 in preparing the analytical sections of this paper.

Dr. McCoy was born in LaPorte City, Iowa on March 18, 1911. He received the Ph.D. degree in Applied Physics rom Iowa State College in 1938. He was associated with the Naval Research Laboratory from 1938 to 1947, occupying ositions of responsibility in charge of sections in the Airborne Radio Division and the Radio Divisions. He joined the aff of the Collins Radio Company in 1947, and since that time headed research groups engaged in work in the microwave eld, recently in the position of Assistant Director of Research and Development. He was made a Fellow of the Institute f Radio Engineers in 1959.

The author hopes that this paper will be considered to be a tribute to the memory of Dr. McCoy, a man whose chnical and administrative qualifications were of the highest, and who was held in the fondest regard by his colleagues.

PART I

oduction

ior to the advent of radio astronomy, our knowledge he Universe outside the earth's atmosphere was almost ely derived from electromagnetic radiations in the ical region" penetrating to the earth's surface. This ation, which has brought us practically all of our nomical knowledge is extremely limited in range, g as it does between 10^{14} cycles/sec and 10^{15} cycles/sec. either side of this frequency region we have been ricted in our investigations by the opacity of the osphere caused by molecular absorptions.

is in the light of this limitation in our traditional rvational method that recent developments in the field microwave radiometry become especially significant. se developments, which have made available for pures of investigation electromagnetic radiation in the frency range from 10^8 cycles/sec. to beyond 3×10^{10}c./ have opened up a whole new vista of discovery. Not has new information regarding the characteristics elestial objects been obtained through an examination heir emissions at radio frequencies, but also the effecly greater frequency range afforded by radio techues has provided means for the discovery of new ural phenomena and even new objects heretofore unctable. In particular, microwave observations are capable of yielding new data regarding the interior characteristics of bodies concerning which optical radiation gives only superficial information. Measurements of lunar temperatures have indicated that the microwave energy emitted by the moon comes, not from its visible surface, but from interior strata buried a considerable distance beneath the surface. Similar techniques are being applied to planetary surfaces with the objective of revealing information regarding the internal constitution of those planets which, at the present time, remain an enigma to us on account of the opacity of their cloud filled atmospheres.

Using radio techniques, extensive investigations of the sun have been made, which have yielded much information, not only about the visible surface, but also regarding disturbances causing the phenomena which have become known as "radio bursts." A fully complete explanation of the mechanism of radio bursts has not yet been developed, but much information has been obtained, and there are strong indications that further work in this field will lead to a more complete understanding of the subject of atomic physics. An example of the use of radio frequencies to obtain new knowledge regarding the photosphere of the sun is the spectacular picture of the sun shown in Figure 1. This visual representation of a contour map, included in this paper with Professor R. N. Bracewell's very kind permission, was made at 9.0 cm using

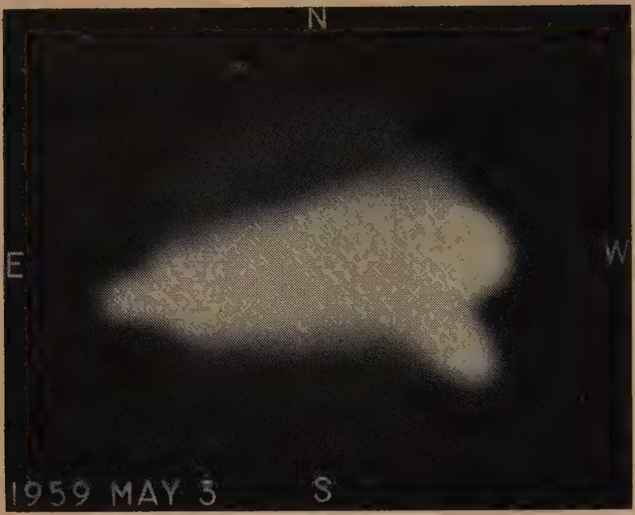

Figure 1 — Visual representation of contour map of sun at nine centimeters.

a large "Mill's Cross" microwave radiometer. It shows important information previously unknown regarding the surface of the sun. A photograph of the antenna, the arms of which are Christiansen arrays, appears in Figure 2. Extensive work has been done on the structure of the galaxy and the "super galaxy" utilizing emissions at various wave lengths. This work, which will be discussed in greater detail somewhat later in this paper, has resulted in mapping the nebular structure of the galaxy, and in determining the characteristics of various types of nebular clouds. Figure 3 shows the 50-foot radio telescope at NRL with which some of this work has been done.

It is beginning to be possible to extend this technique to the Universe as a whole, and much new information has been obtained, which is expected eventually to throw much light on questions of cosmology and cosmogony.

This paper does not purport to cover the field of radio astronomy, which has now grown to such an extent that many textbooks would be required to describe the subject adequately. Instead, it is confined largely to the topic of instrumentation used in radio astronomy, and particularly relates to instrumentation employed at microwave frequencies, in other words, microwave radiometers.

Basic Theory of Operation

Microwave radiometers are generally calibrated in terms of "black body radiation." It is, of course, recognized that some of the results observed cannot be explained on the assumption that the emitting body is in thermodynami equilibrium. Observed equivalent temperatures in th solar corona of 30,000,000° K. cannot, for example, b accounted for, except on the basis of electron transition not related to the actual equilibrium temperature o the corona. Nevertheless, because it is more satisfactory intuitively, it is the current practice to calibrate all observations in terms of temperature. A consideration o basic theory must, therefore, start with the relation between temperature and the intensity of emitte radiation.

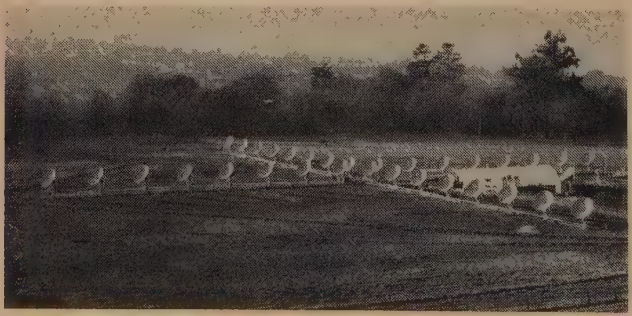

Figure 2 — Professor R. N. Bracewell's cross-type radiometer installation at Stanford University.

A microwave radiometer is, in effect, an extremel sensitive radio receiver. This receiver is provided with highly directional antenna usually incorporating a paraboloidal reflector, and the technique of observation consists of directing the antenna at the object, or region of space under observation and reading the powe picked up by the antenna, as indicated in circuits an equipment associated with the output circuit of th receiver. McCoy, Hepperle, Giberson, and Ringeon have developed the relationships existing between th temperature of the body under observation and th observed receiver input power.

From black body theory, any perfectly absorbing body emits radiation at all frequencies in accordance with Planck's radiation law:

$$\psi_\lambda = \frac{8\pi ch}{\lambda^5} \cdot \frac{1}{e^{\frac{ch}{\lambda kT}} - 1} \qquad (1)$$

where $\psi_\lambda d\lambda$ is the energy density of radiation inside a equivalent isothermal enclosure expressed in joules pe cubic meter in a stream of radiation in the narrow wavelength range $d\lambda$; h is Planck's constant (6.5×10^{-34} joule-seconds); c is the velocity of light (3×10^{8} meters/sec.); k is Boltzmann's constant (1.38×10^{-23} joules/deg. K.); λ is the wavelength in meters and T is the temperature of the black body in ° K.

This equation gives the energy density of the black body at a specific frequency. Figure 4 shows the distribution of radiation as a function of the temperature T and th wavelength, here given in angström units. It is to b observed from this figure that as the temperature of th body increases, the density of radiation on all wavelengths also increases; moreover, the peak of the energy density curve is displaced toward the shorter wavelengths. This shift in the frequency at which maximum density of radiation occurs was first expressed quantitatively by Wien in the following equation:

$$\lambda_m T = 0.294 \text{ cm. degree,} \qquad (2)$$

where λ_m is the wavelength in centimeters at which th energy is at a maximum.

Although Figure 4 shows that by far the highes values of radiation density occur in the optical region nevertheless, an appreciable amount of radiation exist in the long-wave segment of the spectrum. It is th long-wave radiation which is used in the field of microwave radiometry. For this application, some simplification of Planck's law may be made. Expanding th right-hand side of equation (1) in a series, we obtain

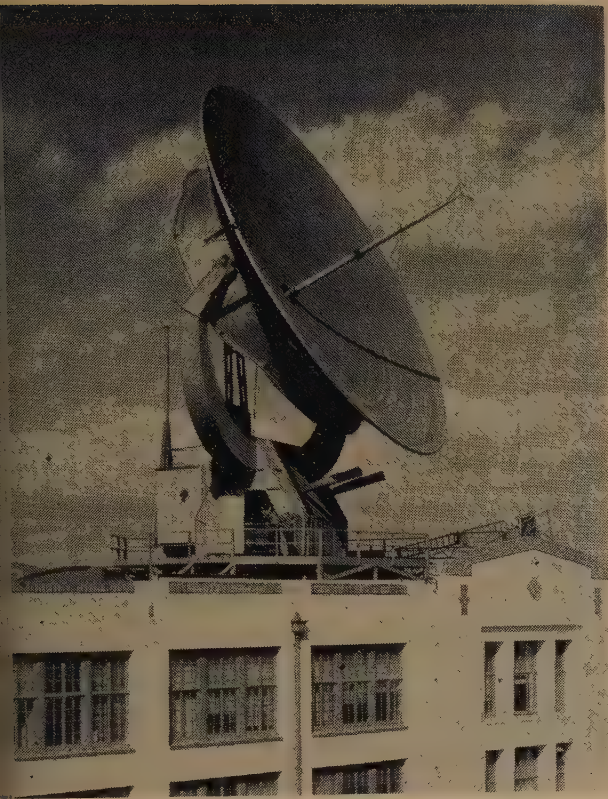

Figure 3 — 50′ radio telescope at NRL.

$$\psi_\lambda = \frac{8\pi ch}{\lambda^5}\left[\frac{1}{\frac{ch}{\lambda kT} + \frac{c^2h^2}{2\lambda^2k^2T^2} + \ldots}\right] \tag{3}$$

The first term in the denominator of equation (3) y be written $\frac{ch}{\lambda k}/T$. It may be seen that if $\frac{h}{k} \ll T$, this term will be small, and the second and ceeding terms will be negligibly small with respect to first term and may be disregarded. It is also evident t as the wavelength, λ, becomes longer, this condi- n becomes more closely approximated. For the relatively g wavelengths employed in microwave radiometry $\frac{ch}{\lambda k}$ in fact, small with respect to T. For example, at the velength of 1.25 cm. used by Dicke et al,[2] McCoy et al,[1] l Piddington and Minnett,[3] the value of $\frac{ch}{\lambda k}$ is 1.14, grees K, compared with average observed temperares generally in excess of 100° K. It may thus be seen t for all practical purposes in microwave radiometry, cept when extremely low temperatures are being obved, all terms in the denominator of equation (3) cept the first may safely be disregarded, reducing the ult to the form:

$$\psi_\lambda = \frac{8\pi kT}{\lambda^4} \tag{4}$$

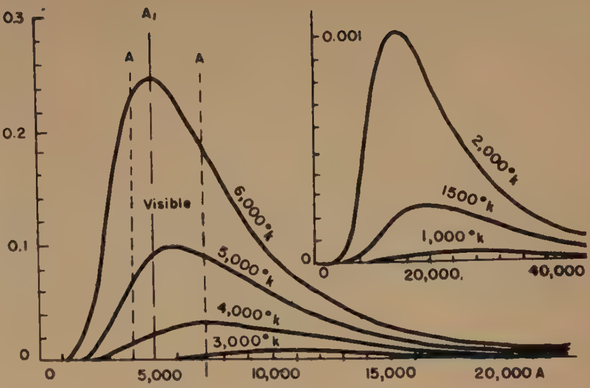

Figure 4 — "Black Body" radiation curves. Ordinate shows relative energy density inside an isothermal enclosure in a wave-length range of one (1) angstrom; abscissa in angstroms.

which is the well-known Rayleigh-Jeans equation, previously verified as sound for infrared wavelengths.

Since ψ_λ is defined as the energy density inside an isothermal enclosure, it is necessary to modify equation (4) before it can be used to predict results in terms of power, measured at a distance by the radiometer. We, therefore, have the following relationships:[4]

By definition, the power emitted in a wavelength range $\triangle\lambda$ extending from λ to $\triangle\lambda$ by a black body per unit solid angle per unit area of its own surface is:

$$p_\lambda = i_\lambda \triangle\lambda, \tag{5}$$

where i_λ is the intensity of radiation, defined so that $i_\lambda \triangle\lambda$ is the rate at which the black body radiates energy in a given direction, per unit solid angle, per unit of its own area as projected on a plane perpendicular to the given direction, and in a wavelength range $\triangle\lambda$. In turn,

$$i_\lambda = \frac{e_\lambda}{\pi} \tag{6}$$

where e_λ is the emissive power of the black body defined so that $e_\lambda \triangle\lambda$ is the radiant energy emitted per unit time, per unit area of the black body in a wavelength range $\triangle\lambda$ extending from λ to $\triangle\lambda$. Moreover, the emissive power of the black body is related to the energy density by the expression:

$$e_\lambda = \frac{c\psi_\lambda}{4}. \tag{7}$$

Substituting the relationships of equations (6) and (7) in equation (5), we obtain:

$$p_\lambda = \frac{c\psi_\lambda \triangle\lambda}{4\pi}. \tag{8}$$

Substituting the value of ψ_λ given by equation (4), we see, finally, that the power radiated into a unit solid angle per square meter of radiating surface is:

$$p_\lambda = \frac{2kTc\Delta\lambda}{\lambda^4}. \tag{9}$$

It will now be convenient to substitute for the factor $\Delta\lambda$ in equation (9) its equivalent bandwidth, Δf, in cycles per second. By differentiating the expression:

$$\lambda = \frac{c}{f}, \tag{10}$$

we obtain the relationship:

$$d\lambda = \frac{-\lambda^2}{c}\, df, \tag{11}$$

which is also valid for finite intervals in the form:

$$\Delta\lambda = \frac{-\lambda^2}{c}\, \Delta f, \tag{12}$$

providing that the intervals are kept small. Substituting this value of $\Delta\lambda$ in equation (9), we obtain:

$$p_\lambda = \frac{2kT\Delta f}{\lambda^2} \text{ watts per m.}^2 \text{ per unit solid angle.} \tag{13}$$

Now, the power P_λ received by a collector at a distance ϱ in meters from the radiating source is evidently a function of the power, p_λ, per square meter of radiating surface, per unit solid angle, as given by equation (13), of the total area of the emitting surface and also a function of the angle subtended at the source by the collector. If the response of the collector, in this case a radio antenna, were uniform in all directions, we might multiply p_λ by the area of the source and the angle subtended, to derive the total power. Actually, the antennas employed with radiometer equipment have directional response patterns. We must, therefore, examine the response of the antenna in a given direction, and integrate to obtain the final result. Consider a differential area of the source, dS. The power received by the antenna from dS, taking into account the fact that a plane polarized antenna will accept only one-half the power impressed upon it, will evidently be:

$$dP_\lambda = \frac{P_\lambda}{2}\, dS\, \frac{A_e}{\varrho^2} \tag{14}$$

where A_e is the area of the antenna.

The expression $\frac{A_e}{\varrho^2}$ is the angle subtended by the antenna, at the source. In practice, it will be more convenient to deal in terms of the effective area of the collector and the angle subtended by the source at the collector. Equation (14) can readily be placed in the desired form by writing the ϱ^2 under the dS, rather than under the A_e, to give:

$$dP_\lambda = \frac{P_\lambda}{2} \cdot \frac{dS}{\varrho^2} \cdot A_e. \tag{15}$$

The expression $\frac{dS}{\varrho^2}$ now represents the differential solid angle subtended by a differential surface area of the source, at the collector. We may, therefore, replace this expression by the differential solid angle,

$$d\Omega = \frac{dS}{\varrho^2}, \tag{16}$$

writing the equation:

$$dP_\lambda = \frac{P_\lambda}{2} A_e d\Omega. \tag{17}$$

The factor A_e is the *effective* area of the antenna, and represents the response of the antenna in the direction, (θ, ϕ), of $d\Omega$. It may be represented by the expression,

$$A_e = \frac{\lambda^2}{4\pi} G(\theta, \phi), \tag{18}$$

where $\frac{\lambda^2}{4\pi}$ is the effective cross-section area of an isotropic antenna, and $G(\theta, \phi)$ is the power gain of the antenna in the direction θ, ϕ with respect to an isotropic antenna. The differential power received by the antenna from ds is, therefore:

$$dP_\lambda = \frac{P_\lambda}{2} \cdot \frac{\lambda^2}{4\pi} G(\theta, \phi) d\Omega. \tag{19}$$

Substituting the value of p_λ from equation (13) and integrating, we have, for the power in watts received by the antenna, from a source having a uniform temperature and subtending an angle Ω at the antenna,

$$P_\lambda = \frac{2k\Delta f}{2\lambda^2} \cdot \frac{\lambda^2}{4\pi} \int_\Omega G(\theta, \phi) d\Omega = \frac{1}{4\pi} \cdot kT\Delta f \int_\Omega G(\theta, \phi)\, d\Omega. \tag{20}$$

Since this equation shows that the power received is independent of λ or f, subscripts indicating λ or f will now be dropped.

Equation (20) is in a form such that the power accepted in a known bandwidth by an antenna having definite characteristics, can be accurately calculated as a function of the temperature of the emitter. In practice, the integral can be quite accurately evaluated for a given antenna, knowing its geometrical characteristics. The power gain, $G(\theta, \phi)$, is defined as the ratio of the power radiated in any given direction to that radiated by an isotropic radiator when it is supplied with equal power s quantity can be accurately determined by calculation interference patterns, or by test. Integration over the d angle subtended by the source then yields the re- red information.

n two cases, it is possible to develop general results ependent of the characteristics of the particular antenna olved. The first of these is the case where the source npletely encloses the antenna. Since $d\Omega$ is the solid le subtended by the source at the collector, then, under se conditions the integration is carried out over the nplete solid angle, and it can be shown that the value the integral is 4π. The total power received is then:

$$P = kT\Delta f. \qquad (21)$$

On the other hand, if the source is much smaller than beam, the gain may be considered constant over the d angle, the value of the integral is $G(\theta, \phi)\,\Omega$, and the ver received is:

$$P = kT\Delta f G(\theta, \phi)\,\Omega, \qquad (22)$$

ere $G(\theta, \phi)$ is the peak gain of the antenna, in the ction of the source.

When the beam width and the source are of comparable , the evaluation of the integral becomes more involved. nson, McCoy and Hepperle[5] have investigated this ject, and have derived a series of curves showing the ue of the integral for various types of antennas, as a ction of the position of the source in the beam, and ratio between the beam width (to half power points) the angular diameter of the source. These curves show , for a paraboloidal antenna of the "tapered feed" e, the value of the integral is $4\pi \times 0.533$ when the rce just fills the beam. Under these conditions, typical solar and lunar observations, the power received is n to be:

$$P = 0.533 kT\Delta f. \qquad (23)$$

t can also be easily shown that the result of equation) applies to the case where the source is large enough fill the entire pattern of the antenna, even without losing the antenna proper on all sides. Practical micro- e antennas are so designed that their gains are almost rely confined to the front lobe in the direction of the or axis of the paraboloid, side and back lobes being ost absent. Moreover, the entire width of the front e, down to zero gain, may be only two or three times width of the beam as conventionally defined to half- ver points. It may, therefore, be said that, as a prac- l matter, equation (21) applies to microwave antennas en the source is two or three times as wide as the m width of the antenna.

ray" Body Theory

The analysis of the preceding sections may be altered apply to bodies which are not perfect black bodies. m black body theory, it is known that the total emis- e power E_G of any body (as, for example, a "gray" ly) is related to the total emissive power E of a black ly at the same temperature by the expression:

$$E_G = AE, \qquad (24)$$

ere A is the absorptivity of the body under consideration. In a similar manner we may write the relationship between the emissive power, at a given wavelength, λ, $e_{G\lambda}$, of a gray body and the emissive power e_λ of a black body, in the form:

$$e_{G\lambda} = a_\lambda e_\lambda, \qquad (25)$$

where a_λ is now defined as the absorptivity of the gray body at the particular wavelength involved, λ. We may now return to equation (7), foregoing, and see that the emissive power of a gray body, in terms of the energy density is:

$$e_{G\lambda} = \frac{a_\lambda c\psi_\lambda}{4}. \qquad (26)$$

It is quite evident from equation (26) that if the analysis embodied in equations (4) to (13) now be repeated, using the subscript "$G\lambda$" for the quantities on the left-hand side of the various equations, we will obtain, for the power received from a gray body, the expression, equivalent to equation (13):

$$P_{G\lambda} = \frac{2ka_\lambda T\Delta f}{\lambda^2} \text{ watts per m.}^2 \text{ per unit solid angle.} \qquad (27)$$

The final result of equation (20) will become:

$$P_{G\lambda} = \frac{1}{4\pi}\, a_f kT\Delta f \int_\Omega G(\theta, \phi)\, d\Omega \qquad (28)$$

where a_f is the absorptivity at frequency f. Equation (39) expresses this relationship in a more general form.

It is to be observed that Equation (28) is a general expression, which also applies to a black body, since it will give correct results for a black body when a_f is taken to be equal to unity. We may, therefore, conveniently define $P_{G\lambda}$ as the power received, P_R by an antenna having characteristics defined by the integral, from a body having an absorptivity a_f and write Equation (28) in the final form, (again dropping the subscript indicating frequency).

$$P_R = \frac{1}{4\pi}\, akT\Delta f \int_\Omega G(\theta, \phi)\, d\Omega. \qquad (29)$$

The absorptivity, a, is the ratio of the power absorbed by the body to the power incident upon the body, and its value is given, in general, by the relationship:

$$a = \frac{P_o - P_r - P_1}{P_o} \qquad (30)$$

where P_o is the incident power, P_r is the reflected power and P_1 is the emergent power. For diffuse media such as the atmosphere or nebulae, $P_r = 0$ and we have

$$a = \frac{P_o - P_f}{P_o} \qquad (31)$$

In terms of wave front potentials, this becomes;

$$a = \frac{E_o^2 - E_i^2}{E_o^2} = 1 - \frac{E_i^2}{E_o^2}. \tag{32}$$

From transmission theory we obtain, for homogeneous materials, the expression:

$$a = 1 - e^{-2\alpha l} \tag{33}$$

where α is the attenuation constant and l is the thickness of the medium, which can readily be evaluated for most materials by calculating the attenuation constant.

Intermediate Absorption

We are now in a position to consider the case where an absorbing medium exists between the source and the antenna. If the medium absorbs it must radiate. Considering, therefore, that the medium is, in itself, a source having an absorptivity a_2, and a constant temperature T_2, and assuming that it fills the entire antenna pattern, we have, (from equation (21)), for the power received by the antenna from the absorbing medium:

$$P_2 = ka_2T_2\Delta f \text{ watts.} \tag{34}$$

The power received from the emitting source will be attenuated by the absorbing medium. Its value, assuming that the absorptivity and temperature of the source are a_1 and T_1, respectively, and that the source also fills the entire antenna pattern, will be:

$$P_1 = ka_1(1-a_2)T_1\Delta f. \tag{35}$$

The total power received by the antenna is:

$$\begin{aligned} P_R &= P_1 + P_2 \\ &= k\Delta f[a_1(1-a_2)T_1 + a_2T_2]. \end{aligned} \tag{36}$$

This equation is useful in determining the correction which must be made for atmospheric absorption, when making celestial observations. In this case, a_2 and T_2 are, of course, the absorptivity and temperature, respectively, of the atmosphere. For a black body emitter, a_1 is unity, and equation (36) may be written:

$$P_R = k\Delta f\ [T_1 - a_2(T_1 - T_2)]. \tag{37}$$

In the case of solar measurements, it may be found that T_2 is sufficiently small with relation to T_1, so that it may be disregarded and the relationship becomes:

$$P_R = kT_1\Delta f(1-a_2). \tag{38}$$

It is however, actually found that a_2 may have an appreciable magnitude, particularly when making observations near the horizon. Under these conditions, the equivalent temperature of the atmosphere, as determined b observing the apparent temperature of an area of the sk not containing a celestial source of radiation, may b found to be as high as 50° K, indicating an atmospheri absorptivity as high as .166 (assuming an atmospheri temperature of 300° K). When making observations nea the horizon, it will, therefore, generally be necessary t take the atmospheric absorptivity into account.

Non-homogeneous Emitters and Absorbers

The foregoing analysis is confined to cases where th emitters and absorbers involved are homogeneous, an the absorptivities and temperatures throughout the masses may, therefore, be considered to be uniform. I practice, media may be encountered in which the absorptivities and temperatures are functions of position. McCo et al[1] have developed general expressions for such case also taking into account possible reflections within or the boundary of the emitting media. They find that, i general, the power received directly by an antenna fro an emitter, without intervening absorption, is:

$$P_R = 2k\Delta f \frac{1}{4\pi}\int_{\Omega} [1-m(\theta,\phi)] \left[\int_{0}^{d} e^{\left(-2\int_{0}^{z}\alpha(\theta,\phi,z)\,dz\right)} \alpha(\theta,\phi,z)\ T(\theta,\phi,z)\,dz\right] G(\theta,\phi)\ d\Omega. \qquad (39$$

Here, $m(\theta,\phi)$ is a function representing the fractio of the power reflected at the boundary of the source a a point in the direction (θ,ϕ) from the antenna; d is th thickness of the emitter in the direction of propagation and $\alpha(\theta,\phi,z)$ and $T(\theta,\phi,z)$ are the attenuation constan and temperature of the emitter, respectively, in the direction (θ,ϕ) from the antenna, and at a depth z.

It is evident that a similar expression might be developed for the case where an absorbing medium exis between the source and the antenna.

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END PART I

THE EFFECT OF SILVER PLATING ON ATTENUATION AT MICROWAVE FREQUENCIES

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Andrew Corporation · Chicago, Illinois

I INTRODUCTION

Due to the low resistivity and the low chemical ac- vity of silver, it seems intuitively reasonable that silver lating should not only decrease the losses but also ne deterioration due to ageing of brass and copper aveguides. However, since about 1950 various inves- gators have been compiling evidence which shows nat this is not necessarily so. Indeed, under certain onditions, silver plating has been found to enhance osses considerably and several investigators recommend rongly against its use.

Factors influencing the attenuation of metallic sur- aces at microwave frequencies are the roughness of he surface, its composition, porosity, corrosion, re- istivity and the operating frequency. In order to dis- uss these effects quantitatively, we introduce four basic uantities.

$$(1)\quad R_s = \left(\frac{\mu\ \omega}{2\ g}\right)^{\frac{1}{2}} \qquad (3)\quad \alpha = R_s f_1\ (\lambda, a, b)$$

$$(2)\quad \delta = \left(\frac{2}{\mu g \omega}\right)^{\frac{1}{2}} \qquad (4)\quad Q = \frac{f_2\ (\lambda, a, b)}{R_s}$$

where

R_s = Surface resistance or intrinsic resistance, a quantity peculiar to the medium and independent of the geometry of the wave.

δ = Skin depth, a measure of the penetration of current into the medium.

α = Attenuation constant.

Q = Figure of merit, a measure of the sharpness of frequency response in cavity resonators.

f_1 & f_2 Are well defined functions of the geometry of the waveguide.

ω = Angular frequency.

g = dc Conductivity = reciprocal of dc resistivity of the medium.

λ = Wavelength.

μ = Permeability of the medium.

a, b Are dimensions of a transmission line component.

II. Methods of Comparing Losses

The surface resistivity R_s is a good measure of metallic loss because it is independent of the dimensions of the microwave device and appears in the expressions for α and Q. Its measured value, which we shall call "effective R_s," is consistently found to be higher than the value predicted by (1). (After Benson[14] pointed out that this discrepancy is often due in part to an inaccurate value of g, considerable care has been taken to determine the dc conductivity in each individual case instead of using the handbook value). The effective R_s can be measured in two ways. The first, described by Benson,[14] is particularly applicable to waveguides. It makes use of (3) where α is measured directly by a slotted line determination of VSWR. The second, used for wires and coaxial cables, is an elegant determination of Q developed by Beck.[5] Formula (4) then gives the effective R_s.

In order to eliminate geometrical factors, experimental results are usually quoted as ratios between measured and theoretical values. If we denote a measured value by a prime, (1), (3) and (4) give

$$\frac{R_s'}{R_s} = \frac{\alpha'}{\alpha} = \frac{Q}{Q'} = r$$

While various investigators record the first three ratios, we shall use r throughout.

III. Effect of dc Resistivity

In order to compare losses in various metals, the measured loss is sometimes compared to the theoretical loss in copper for the same frequency, and assuming that $\mu = 1$ for all practical conductors, we see from (1) that R_s'/R_s copper $= \left(\frac{g \text{ copper}}{g'} \right)^{\frac{1}{2}} = (\varrho)^{\frac{1}{2}}$ where ϱ is the relative resistivity. Table 1 shows that while this is a significant factor for brass and other metals, we can assume that the theoretical R_s of silver is equal to that of copper. (This is justified because in this report R_s appears only in the ratio $\frac{R_s'}{R_s} = r$. While the above assumption introduces an error in r of about .03%, other factors cause r to vary much more strongly). Hence r is, in the case of silver, not only a measure of the validity of the theory but also a comparison with a waveguide component used at the same frequency and having the same dimensions, but made of pure copper.

TABLE 1

Material	Relative Resistivity	R_s'/R_s Copper
Silver	.95	.97
Copper	1.00	1.00
Coin Silver	1.22	1.10
Brass	2.4	1.55

IV. Factors Affecting Losses

In Table 2 some of the values of r recorded by various investigators are listed. They will be discussed in detail below, but it is at once evident that almost all are greater than unity and that they tend to increase with frequency. Benson[14] contends that roughness alone accounts for these phenomena. While this is largely true, Lending[13] points out that ageing, corrosion and porosity affect r in different manners.

V. Influence of Roughness on r

If the magnitudes of the surface irregularities are small compared to the skin depth, the current flow will be little affected. If, however, they are large, the current will tend to flow in an irregular path following the surface and hence encounter a path larger than that calculated for a smooth surface. Since R_s is calculated for a perfectly flat surface, this accounts for the fact that r is larger than unity and increases with frequency. The skin depth of both copper and silver ranges from about 100 μ-inches at 1 kmc to about 10 μ-inches at 50 kmc. The work of Benson shows that irregularities of up to 600 μ-inches occur in silver plated surfaces, depending on the method of plating and polishing.

This suggests, then, that at high frequencies, above say 9 kmc, we can safely assume that $\gamma \gg \delta$ where γ is the rms roughness (usually obtained by some micro-measurement) of the surface. With this assumption, Benson has introduced so-called roughness factors, based on microscopic measurements, into the attenuation formula. They simply account for the physical lengthening of the current path along the surface of the metal. His theoretical values of r agree very well with those measured, so long as the roughness is not of dimensions too small to be measured, [22].

At lower frequencies the assumption $\gamma \gg \delta$ does not hold. At 3 kmc Lending has found a nearly linear relationship between γ/δ and r up to about $\gamma = 2\delta$.

At 1 kmc the skin depth is so large that the effect of conductivity on r may overshadow that of roughness. This accounts for the value $r = .83$ for cavity resonators.

VI. Influence of Ageing, Corrosion and Porosity on r

As is evident from Table 2, ageing considerably increases r. This may be due to one of two reasons. If the corrosion product is non-conducting, the increase in r will be due primarily to the roughening of the surface. If it is a conductor, part of the current will flow in this layer and encounter a higher dc resistivity.

The effect of porosity on r is difficult to determine, but Lending[13] estimated that at 3 kmc, it accounts for a rise of about 20% above unit.

VII. Surface Quality of Silver Plating

The results obtained for ordinary silver plating are very disappointing. Due to the chemical and physical properties of silver, the layer of plated metal usually follows the irregularities of the base metal closely and often exaggerates them. If the base metal is buffed carefully and the silver mechanically polished, values of r down to 1.23 may be obtained at 9 kmc, but if buffing is done less carefully, r rises to over 2. The speed at which plating is done critically affects the surface characteristics as expected. For a slow bath, r of 1.37 may be obtained while for fast baths it becomes very high. Care must be taken in silver plating that the thickness of silver is uniform. If an anode outside the waveguide is used, the thickness inside may be as low as 1/25 the nominal value. In that case it may happen that current flows inside the base metal, resulting, of course, in high α, especially at low frequencies where δ is large.

In general, the effect of surface roughness is much stronger than that of higher conductivity in silver plating. Results of measurements by Beck and Dawson[5] show that well finished pure copper or brass waveguide, copper plated, electropolished or chemically polished metals all give much better results.

It is only at relatively low frequencies where high Q is required and careful processing economically possible, that silver plating may show an advantage over copper or brass.

Coin silver shows about the same characteristics as pper, at times a little better, but its ageing prop- es, discussed below, make its use questionable.

Very good results have been obtained by Benson[16] bright silver plating (including turkey-red oil and bon disulphide in the cyanide bath). These chem- s give silver better levelling properties so that oother surfaces are expected and obtained. The ue r = 1.00 for one sample is calculated from micro- asurements, but it is a good indication of the possible lity of this type of plating. However, the process unreliable. Sometimes the surface is even rougher n that of the base metal. It is also too expensive critical for ordinary use.

Work has been done on chemical and electrical shing of various surfaces with excellent results.[16] ctropolish is a method applicable to silver, but the age is very critical and the process expensive.

I. Ageing and Corrosion of Silver Plating

rom Table 2 it is seen that silver plated surfaces t very unfavorably to ageing and corrosion. The corrosion products of silver are thought to be fair conductors, so that at high frequencies r increases enormously with ageing. If the corroded layer is cleaned off, r drops, but not to the original value because the surface cannot be made as smooth as it was before without extensive treatment.

A method of plating, called periodic-reverse (P-R), improves the original surface and hence its reaction to corrosion, but it is still not better than copper. A protective lacquer, or a thin rhodium flash, also improve the corrosion and ageing characteristics, but introduce a slightly higher initial loss.

IX. Comments on Ageing and Properties of Copper, Brass, and Tellurium Copper

Lending[13] reported that "The Mechanical Properties of Pure Copper usually limit its use in Waveguide Systems. In addition, its corrosion properties resemble those of silver."

Allison and Benson[20] reported that "For normal-drawn copper tubes the measured values of attenuation were

TABLE 2

Copper r	Coin Silver r	Silver Plating r
		Fresh Silver Plating with Rhodium Flash Measured 0.83 relative to measured value for cu (21)
1.19 (13) Drawn Wire — Oxidized Surface	1.08 (13) Drawn Rod — Oxidized Surface	1.34 (20) (13) Silver Plated Brass Guides
1.21 (13) Drawn Wire — Oxidized Surface	1.31 (13) Drawn Rod — Oxidized Surface	
	1.29 (13) Drawn W.G. — Oxidized Surface	
1.135 (5) Commercial Wire 1.02 (5) Immediately after Electro Polishing 1.12 (5) 18 weeks after Electro Polishing 1.41 (5) Aged out-of-doors, 4½ months	1.16 (5) Commercial Alloy	1.37 to 2.27 (5) Immediately after silver plating — depends on plating speed. 1.23 to 2.05 (11) Immediately after silver plating — depends on buffing. 1.58 (13) Immediately after silver plating on brass
1.102 to 1.120 (20) Normal — Drawn Copper Waveguide		1.58 (20) Silver Plated from Cyanide Bath
1.32 (13) Drawn Waveguide — Oxidized Surface*	1.28 (13) Drawn Waveguide — Oxidized Surface	1.33 (13) After ageing — Periodic Reverse (P-R) Process
1.6 (13) Drawn Waveguide — Oxidized Surface*	1.73 (13) Drawn Waveguide — Oxidized Surface 1.65 (13) Drawn Waveguide — Aged	Up to 2.60 (13) Few months after ageing 1.74 (13) After ageing — Periodic Reverse (P-R) Process

1. Numbers in parentheses refer to References.

2. For Definition of r refer to Paragraph 2.

*Lending[13] gave these same values for aged copper samples.

from 10.2 to 12 percent greater than the theoretical values. The corresponding figures for normal-drawn brass tubes being 6 to 7.4 percent. . . . Brass tubes always give attenuations nearer to the calculated values than copper tubes for a particular kind of guide, possibly due to the softer nature of the copper and its consequent greater liability to scratching and/or to the higher friction between copper and the drawing dies."

Beck and Dawson[5] reported that "the effective conductivity of freshly electropolished copper is seen to drop in value due to ageing in the laboratory, and to drop further if aged outdoors, as would be expected. To protect a freshly polished copper surface, DuPont clear lacquer was selected, because it was considered to be good for this purpose, and was found to cause a negligible increase in loss at these frequencies" (around 9 kmc).

Lending[13] reports that "within the normal range of utilization of 90-10 brass, deviations of r greater than five percent above theoretical are high. Its ageing characteristics are excellent. Increases in attenuation in operations below 12 kmc after ageing from 0 to 10 percent have been consistently reported. Because of its mechanical and ageing characteristics, brass is frequently the ideal choice for use in waveguide systems."

Lending[13] also reported that "Manufacturers of waveguide tubing have indicated willingness to use tellurium copper rather than brass or silver in waveguide tubing. Waveguide samples of tellurium have been measured before and after exposure to salt spray at 9.9 kmc with the following results: (1) 50 hours — no significant change; (2) 150 hours — 20 percent rise in attenuation."

X. Conclusions

In spite of the fact that at present many commercial microwave components are made of silver or silver plated metals, this practice is generally discouraged. Silver or silver plating may be necessary for mechanical considerations and at low frequencies it is necessary for high Q cavity resonators, but in general well finished brass or copper has the same or better attenuation characteristics. In Table 3 recommendations concerning the use of silver and silver plating are listed.

TABLE 3

Recommendations

		Freq.-below 12 kmc	Freq.-above 12 kmc
Long runs Low α	Silver	Too expensive	Discouraged
	Silver Plate	Discouraged	Not used
Short runs α not critical	Silver	Use tellurium copper	Use tellurium copper
	Silver Plate	Good for High-Q application	Use P-R plating if necessary

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Note: 7, 9 and 12 were intentionally omitted.

SIMPLE CALCULATIONS OF WAVEGUIDE WAVELENGTH

JORGEN P. VINDING

SIERRA ELECTRONIC CORPORATION
Menlo Park • California

The relation between the cut-off wavelength λ_c, the ee space wavelength λ_o, and the guide wavelength λ_g, usually presented in a form that does not lend itself ery well to slide rule computation, and when it is atmpted to find one of these from a knowledge of the her two it is common to go through a considerable mount of "pencil pushing;" it is also common to use a place table of squares in order to obtain a 3-place result.

By introducing an angle θ as defined below it becomes ossible to carry out these calculations on a slide rule with tle or no mental calculation. In cases where extreme curacy is required, a 4-place logarithm table can take e place of the slide rule; this is rarely necessary unless , is within ½% of λ_c or less than 1/10 of λ_c.

$$(1)\quad \lambda_g = \frac{\lambda_o}{\sqrt{1-\left(\frac{\lambda_o}{\lambda_c}\right)^2}}$$

$$(2)\quad \left(\frac{1}{\lambda_g}\right)^2 = \left(\frac{1}{\lambda_o}\right)^2 - \left(\frac{1}{\lambda_c}\right)^2$$

The usual form of the equation for λ_g, (1), can be reritten as (2) which has a form similar to the Pythaorean and suggests the triangle shown (fig. 1). The angle is defined as the angle in this triangle between the sides $\frac{1}{\lambda_o}$ and $\frac{1}{\lambda_g}$. It can be found from any one of these quations:

$$\sin\theta = \frac{\lambda_o}{\lambda_c} \qquad \cos\theta = \frac{\lambda_o}{\lambda_g}$$

$$\tan\theta = \frac{\lambda_g}{\lambda_c} \qquad \cot\theta = \frac{\lambda_c}{\lambda_g}$$

Once θ is found the missing "side" can be found from he of the equations:

$$\lambda_o = \lambda_c \sin\theta = \lambda_g \cos\theta$$

$$\lambda_c = \frac{\lambda_o}{\sin\theta}$$

$$\lambda_g = \frac{\lambda_o}{\cos\theta}$$

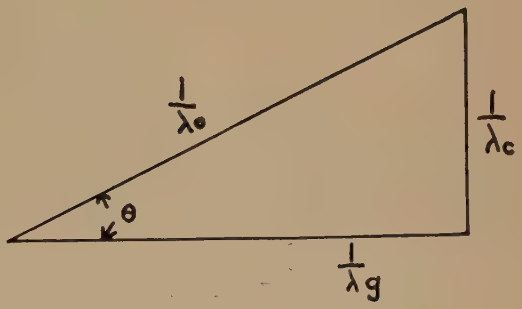


Figure 1.

These equations are used to set up the following procedures for finding each of the three wavelengths on a slide rule which has scales of sin x and tan x referred to scale C. Very similar procedures can be worked out for the type of slide rule with sin x and tan x referred to scale D.

The geometrical figure from which the equations and procedures are derived is simple enough so that engineers who do not remember the equations can derive them and use them in less time than the usual method would take.

Procedures

I To Find λ_g:

a. Set 10 or 1 on scale C opposite λ_c on scale D
b. Set cursor over λ_o on scale D and read θ on sin scale
c. Leave cursor; set θ on cos scale or (90-θ) on sin scale under cursor
d. Read λ_g on scale D opposite 10 or 1 on scale C

Caution

If λ_o is less than 1/10 of λ_c the angle θ is less than 5.7 degrees and the procedure must be modified, or an approximation can be used:

$$\lambda_g \approx \lambda_o\left[1 + \tfrac{1}{2}\left(\frac{\lambda_o}{\lambda_c}\right)^2\right]$$

II To Find λ_c:

a. Set 10 or 1 on scale C opposite λ_g on scale D

b. Set cursor over λ_o on scale D and read θ on cos scale or $(90-\theta)$ on sin scale.

c. Leave cursor; set θ on sin scale under cursor

d. Read λ_c on scale D opposite 10 or 1 on scale C

Caution

If λ_o is less than 1/10 of λ_g the angle θ is more than 84.3 degrees and the procedure must be modified, or an approximation can be used:

$$\lambda_c \approx \lambda_o\left[1+\tfrac{1}{2}\left(\frac{\lambda_o}{\lambda_g}\right)^2\right]$$

III To Find λ_o if $\lambda_g < \lambda_c$:

a. Set 10 or 1 on scale C opposite λ_c on scale D

b. Set cursor over λ_g on scale D and read θ on tan scale

c. Move cursor to θ on sin scale

d. Read λ_o on scale D under cursor

Caution

If λ_c is more than 10 × λ_g the angle θ is less than 5.7 degrees and the procedure must be modified, or an approximation can be used:

$$\lambda_o \approx \lambda_g\left[1-\tfrac{1}{2}\left(\frac{\lambda_g}{\lambda_c}\right)^2\right]$$

IV To Find λ_o if $\lambda_g > \lambda_c$:

a. Set 10 or 1 on scale C opposite λ_g on scale D

b. Set cursor over λ_c on scale D and read $(90-\theta)$ on tan scale

c. Move cursor to $(90-\theta)$ on sin scale

d. Read λ_o on scale D under cursor

Caution

If λ_g is more than 10 × λ_c the angle θ is more than 84.3 degrees and the procedure must be modified, or an approximation can be used:

$$\lambda_o \approx \lambda_c\left[1-\tfrac{1}{2}\left(\frac{\lambda_c}{\lambda_g}\right)^2\right]$$

Dielectric Filled Waveguide

In cases where the waveguide is completely filled with a material of relative dielectric constant ϵ the same equations and procedures can be used if all wavelengths are measured in this material.

It is convenient to use these designations:

$$\lambda_1 = \frac{\lambda_o}{\sqrt{\epsilon}}$$

is the wavelength in an infinite space with relative dielectric constant ϵ.

λ_{1g}

is the guide wavelength measured in the completely filled waveguide.

λ_{1c}

is the value of λ_1 for which the waveguide cuts off.

Note that λ_{1c} depends on the dimensions of the dielectric filled guide in exactly the same manner as λ_c depends on the dimensions of an empty guide.

λ_{1c} does *not* depend on ϵ.

$$\lambda_{oc} = \sqrt{\epsilon}\,\lambda_{1c} = \frac{c}{f_c}$$

is the free space wavelength corresponding to cut-off, and c is the velocity of light in vacuum.

f_c

is the cut-off frequency; it depends on ϵ.

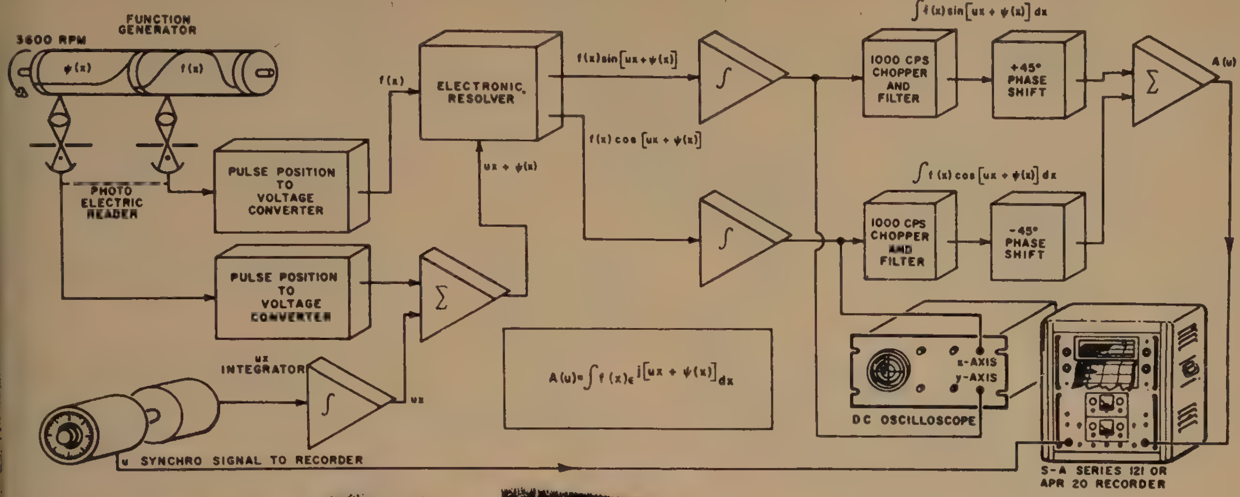
Using the wavelengths defined above it is readily seen that

$$\lambda_{1g} = \frac{\lambda_1}{\sqrt{1-\left(\frac{\lambda_1}{\lambda_{1c}}\right)^2}}$$

$$\left(\frac{1}{\lambda_{1g}}\right)^2 = \left(\frac{1}{\lambda_1}\right)^2 - \left(\frac{1}{\lambda_{1c}}\right)^2$$

Since the equations have exactly the same form it is obvious that the procedures can be used unchanged if λ_{1g} is substituted for λ_g, λ_1 is substituted for λ_o, and λ_{1c} is substituted for λ_c.

Simplified block diagram of Model CF-1. Amplitude and phase input functions are plotted on graph paper for presentation. Integration is observed on a dc oscilloscope. Absolute magnitude is recorded on any S-A Series 121 or APR 20 Antenna Pattern Recorder with a logarithmic response.



3600 RPM
FUNCTION GENERATOR
$\psi(x)$
$f(x)$
PHOTO ELECTRIC READER
PULSE POSITION TO VOLTAGE CONVERTER
PULSE POSITION TO VOLTAGE CONVERTER
$f(x)$
ELECTRONIC RESOLVER
$ux + \psi(x)$
ux INTEGRATOR
ux
u SYNCHRO SIGNAL TO RECORDER
$f(x)\sin[ux+\psi(x)]$
$f(x)\cos[ux+\psi(x)]$
$\int f(x)\sin[ux+\psi(x)]\,dx$
$\int f(x)\cos[ux+\psi(x)]\,dx$
1000 CPS CHOPPER AND FILTER
1000 CPS CHOPPER AND FILTER
+45° PHASE SHIFT
-45° PHASE SHIFT
$A(u)$
$A(u)=\int f(x)\epsilon^{j[ux+\psi(x)]}dx$
x-AXIS
y-AXIS
DC OSCILLOSCOPE
S-A SERIES 121 OR APR 20 RECORDER

To solve

$$A(u)=\int_{-1}^{1} f(x)\,\epsilon^{j[ux+\psi(x)]}\,dx$$

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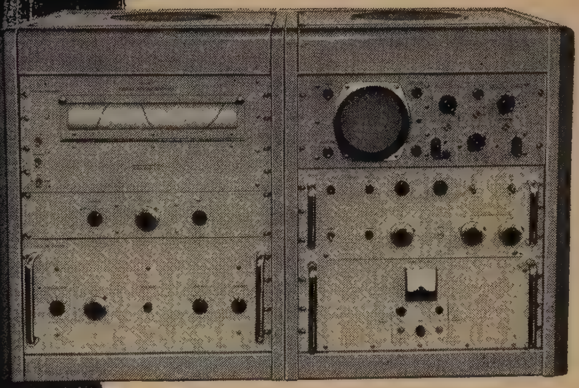

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4

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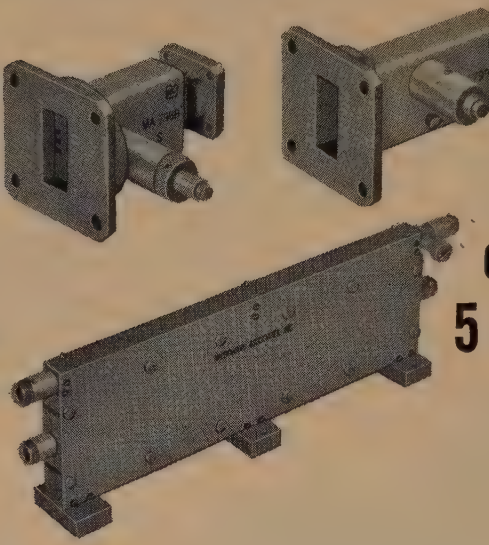
11 kMc input @ 500 mw



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SPECIFICATIONS

	INPUT				OUTPUT				
Model	Connector Type UG-	Frequency Input kMc/s	Band	mw input	Connector Type UG-	Frequency Output kMc/s	Band	Conversion Loss (max.)	Output mw
MA796	23/U	0.26 — 0.28	P	20	23/U	1.30 — 1.43	L	13db	1
MA797	23/U	1.30 — 1.43	L	100	23/U	5.22 — 5.72	C	15db	3
MA798A	39/U	9.0±150Mc	X	500	596/U	18.0±300Mc	K	17db	10
MA798B	39/U	10.0±150Mc	X	500	596/U	20.0±300Mc	K	17db	10
MA798C	39/U	11.0±150Mc	X	500	596/U	22.0±300Mc	K	17db	10
MA798D	39/U	12.0±150Mc	X	500	596/U	24.0±300Mc	K	17db	10
MA799A	39/U	9.0±100Mc	X	500	600/U	27.0±300Mc	Ka	20db	5
MA799B	39/U	10.0±100Mc	X	500	600/U	30.0±300Mc	Ka	20db	5
MA799C	39/U	11.0±100Mc	X	500	600/U	33.0±300Mc	Ka	20db	5

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Industry News

(Continued from page 30)

Micromega will engage in research, development and production of microway components and sub-systems and will specialize in microwave solid-state electronics.

Financial backing for the new concern will be provided by FXR, Inc.

A 10,000 square foot plant at 4134 De Rey Avenue, in Venice, Calif., will house the offices, laboratories and precision shop facilities of the new firm. The Wes Coast sales office and service facilities of FXR, Inc. will also be located at the same address.

Mr. Henry Feldmann, President o FXR, indicated that "he was very please with this affiliation because it will mak an experienced research and developmen capability available to FXR, which will enhance its position in the microwav field. In particular, it is planned to investigate the application of solid-stat electronics to microwave instrumentation."

Mr. Strumwasser, of Micromega, expressed similar enthusiasm about association with FXR, Inc. and indicated tha "the prestige and know-how of FXR i the manufacture of precision microwav components and their experience in marketing and sales will be of invaluabl benefit to the new firm."

— *mwj* —

AEL - NUCLEAR RESEARCH AGREEMENT

American Electronic Laboratories, Inc of Philadelphia, has announced the signin of an agreement with Nuclear Researc Corporation of Southampton, Pa., tha grants American Electronic Laboratories a option for a period of one year to purchase a majority interest in Nuclea Research.

AEL develops and manufactures communication, electronic and electro-medica research equipment that is sold throughou the world. Nuclear Research produce gamma gauges and other nuclear tes equipment.

The agreement was jointly announce by C. J. Fowler, Chairman of the Boar of AEL and Norman Cherry, President o Nuclear Research. AEL will provide financial, administrative and sales assistanc to Nuclear Research.

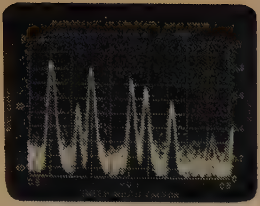
— *mwj* —

NEW QUARTERS FOR PAGE

Page Communications Engineers, Inc designers and builders of global telecommunications systems who began operatio in Washington, D.C., has moved into th "Page Communications Building," ju completed in the Georgetown area o Washington. The 4-story, brick buildin is located at 2001 Wisconsin Ave., N.W

The Page Company's Research and D velopment laboratories, formerly locat in suburban Maryland, are installed o the ground floor. The new facilities a capable of prototyping equipment as larg as 100 kw transmitters. A 100-acre fiel

Discrete signals in noise background are easily detected and measured on SB-7bz display. Automatic high sampling rate (6.7/sec.) speeds measurements.



versatility + economy

Panoramic's ULTRASONIC SPECTRUM ANALYZER SB-7bz
1kc to 300kc

Up to 25µv sensitivity and exceptional dynamic range with simple, convenient operation are combined in one compact, low-priced instrument. Standard equipment at military installations and in industry, the SB-7bz is ideally suited for:

- Ultrasonic noise and vibration analysis
- Communication system analysis—wire carrier and VLF radio
- FM Telemetry subcarrier channel analysis
- General Fourier analysis

The SB-7bz features:

- Variable sweep width: 0 to 200kc
- Amplitude scales: 40db log, 20db linear and 2.5db expanded
- Resolution: variable from 100 cps to 2kc
- Sensitivity: 250µv for full scale deflection, calibrated to measure signals as low as 25µv
- Sweep rate: 6.7/sec., synchronized to power line, plus provisions for variable sweep rates when used with accessory equipment
- 5" high-persistence CRT Tube

Write, wire, phone now for detailed specifications bulletin; and ask to be put on our regular mailing list for the PANORAMIC ANALYZER featuring application data.

dependable CERTIFIED SPECIFICATIONS for accurate data

the pioneer is the leader

Panoramic
RADIO PRODUCTS, INC.

556 Fulton Ave., Mt. Vernon, N.Y.
Phone: OWens 9-4600
Cables: Panoramic, Mount Vernon, N.Y. State

Circle Reader Service Card 30

station is also maintained on Taylors Island, Md., in Chesapeake Bay.

The Page Communications Library, considered among the best in this area, occupies greatly enlarged quarters adjacent to the Engineering Directorate.

According to E. C. Page, Founder and President, steady growth and further expansion, planned since the firm became a wholly-owned subsidiary of Northrop Corp. last year, prompted the move. The new home office more than doubles the space formerly occupied in downtown Washington. Today, Page employs over 750 persons and maintains branch or field offices in San Francisco, Hawaii, Guam, Manila, Beirut, London, and Madrid. The firm also has affiliates in Canada, Italy and Japan.

— mwj —

MODERNIZATION PROGRAM AT GORHAM

Plans for modernizing microwave foundry facilities at Gorham Electronics, Division of the Gorham Mfg. Co., Providence, R.I., were accelerated with the breaking of ground for additional facilities installations.

Automatic sand handling equipment, automatic moulding equipment and the latest type melting furnaces are included in this program. Investment casting facilities were installed last year at the start of the modernization program.

Gorham officials stated that just under $200,000 is being spent, attributing the rise in demand for microwave equipment as having made the program necessary.

Final date for completion of the Foundry modernization program is estimated by July 1st of this year.

— mwj —

CALDWELL JOINS AIRTRONICS

C. L. Caldwell has joined Airtronics, Inc. the Scovill Manufacturing Company electronics subsidiary, 5522 Dorsey Lane, Washington 16, D.C. (Bethesda, Md.) as Director of Marketing.

Mr. Caldwell was formerly Washington Regional Manager for Radiation, Inc. He has also held top administrative posts with Bendix Aviation (Pacific Division); RCA Communications; Westinghouse Electric Corporation; Gulf Oil Corporation and the Wallace Aviation Service.

Mr. Caldwell hails from Washington State where he received a Bachelor's Degree in Electrical Engineering at Pullman.

— mwj —

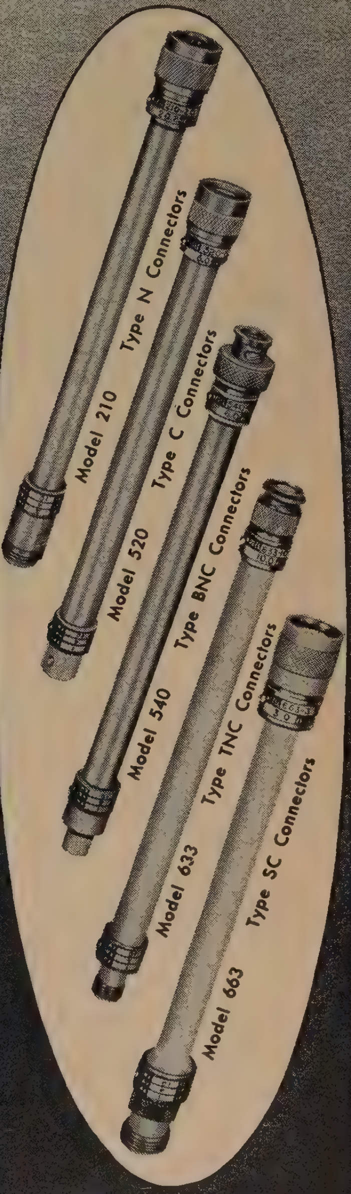
WEINSCHEL

FIXED COAXIAL ATTENUATORS

1 to 12.4 KMC

50 Ohms 1 to 20 db

Connectors: Type N, C, BNC, TNC or SC. Each type with male/female, double male or double female connectors. Made with Weinschel Film Resistors for maximum stability.



WE CO

Write for complete catalog, specifying frequency range of interest.

Weinschel Engineering
KENSINGTON, MARYLAND

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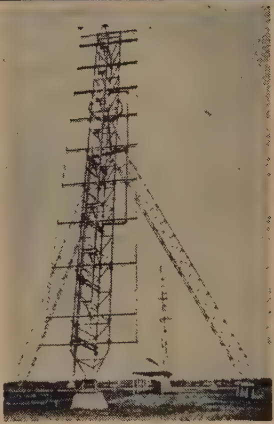
antenna
KNOW-HOW

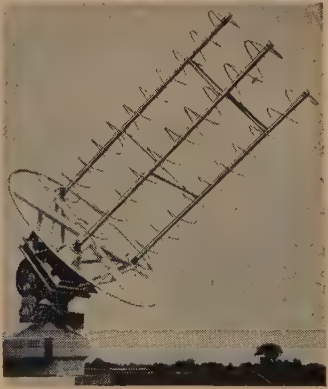
Test site where Taco antennas are performance-proved.

Taco offers capabilities in practically every antenna and antenna system area. These capabilities include conception, development and production, as well as field erection of antennas for all purposes. In addition, Taco offers a complete line of parabolic reflectors ranging from 4′ to 32′, along with all types of feed systems, ruggedized yagis, helical antennas with or without reflectors, airborne and submarine antennas, and complete tracking systems.

Whatever your antenna needs, check with Taco first . . .



Doploc antenna system for tracking orbital bodies. Designed, produced and installed by Taco.



Taco telemetering antennas for all commercial and military needs.

• ***WRITE FOR FREE COPY OF TECHNICAL DATA...***

TACO

SHERBURNE, NEW YORK

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LEONARD SWERN PROMOTED AT SPERRY

The Sperry Microwave Electronics Company recently announced the promotion of Leonard Swern to Engineering Department Head. In this capacity he is responsible for all microwave solid-state activities, as well as research and development of microwave system components and antennas.

A former Section Head for Applied Physics, Mr. Swern joined Sperry Microwave ten years ago after receiving his M.A. in physics from Columbia University.

He is a member of the American Physical Society, the Institute of Radio Engineers and is serving on the Editorial Board of Transactions for the Professional Group of Microwave Theory and Technique. Mr. Swern is known in various technical circles through his past and present work and as co-author of a number of papers.

Past works have included design of microwave bolometers, research involving interactions between microwaves and matter, and microwave research and advanced developmental work on the properties of ferrites and other anistropic media at microwave frequencies.

— mwj —

TWO APPOINTMENTS BY BENDIX - RED BANK

Red Bank Division of the Bendix Corporation has recently appointed Mr. Dwight L. Umstead, Jr. as Sales Engineer for the Electron Tube Products department. Mr Umstead will be working out of the West Coast office at Burbank, California, and will be servicing in conjunction with Mr. Eugene W. Swenarton the states of Washington, Oregon, Idaho, California, Nevada, Utah and Arizona.

The Division has also appointed Mr. William Connaughton, Jr. as Sales Engineer for the Electron Tube Products department. Mr. Connaughton will be temporarily working out of Mattapan, Massachusetts, and will be covering the New England states of Maine, New Hampshire, Vermont, Massachusetts, Connecticut and Rhode Island. A permanent New England office address will be announced at a later date.

— mwj —

CULLEN NAMED DIRECTOR OF LFE'S INSTRUMENT DIVISION

aboratory For Electronics, which re- tly reported acquisition of additional rters for its Instrument Division at Beacon Street, Boston, announces the ointment, by Henry W. Harding, Presi- t, of Mr. John N. Cullen, Director of Division. Mr. Cullen is responsible

all sales and Contract Administration, neering, and manufacturing operations his Division which designs, develops, manufactures Microwave Oscillators Microwave Stability Testers for elec- ics firms and research laboratories ughout the country. Mr. Cullen will market the Division's equipment in pe through LFE's International Divi-

rior to his LFE appointment, Mr. Cul- was Assistant Manager, Systems Divi- , Epsco Inc. He has also served as Engineer for Fischer and Porter Hatboro, Pennsylvania; Production ager for Louis Allis Company, Mil- kee; and Petroleum Engineer for Stan- Oil Company of California.

r. Cullen received a Master's Degree Harvard Business School in 1952, his B.S. in Mechanical Engineering Cornell University. He is a veteran he United States Navy, and resides his wife and four children in Natick, sachusetts.

— mwj —

TERSON APPOINTED AIRTRON EST COAST SALES MANAGER

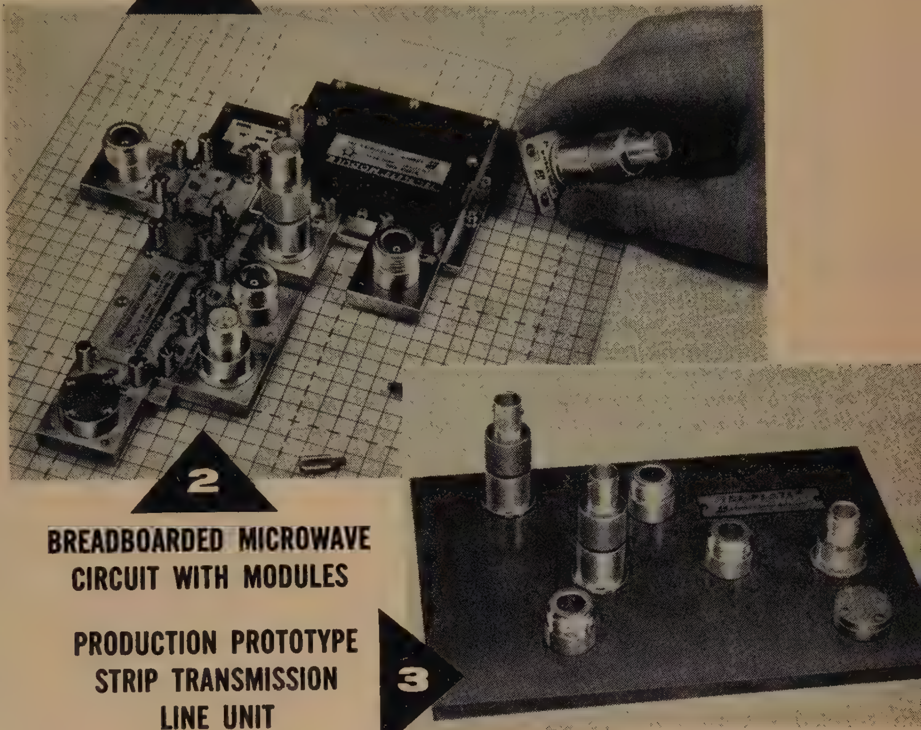
obert Patterson has been appointed manager for the Pacific Coast facility irtron, Inc., in Los Angeles, a division itton Industries, effective immediately. announcement was made by David S. je, manager of the facility which manu- ures microwave components.

r. Patterson has had ten years experi- in sales and engineering in the elec- ics industry. Formerly with Robertshaw- on Controls in the San Francisco area, vas largely responsible for incorporation lectronic and pressure control devices he Polaris missile and the Explorer s of satellites.

— mwj —

AS SIMPLE AS . . . 1 • 2 • 3

1 TRI-PLATE® MODULES



2 BREADBOARDED MICROWAVE CIRCUIT WITH MODULES

PRODUCTION PROTOTYPE STRIP TRANSMISSION LINE UNIT 3

HURDLE TIME AND COST BARRIERS WITH MICROWAVE STRIP TRANSMISSION MODULES

This balanced and single-ended mixer with common L. O. supply was breadboarded in just minutes with new Sanders TRI-PLATE Modules.

These revolutionary new Microwave Strip Transmission Line components with integral connectors permit you to go from design, to breadboard, to prototype with known characteristics without waste of time or effort.

Versatile, reusable TRI-PLATE building blocks eliminate the need for costly, time-consuming delays in breadboarding circuit designs for testing. Microwave circuits such as mixers, duplexers, and modulators can be actually "breadboard-designed" into working circuits in just minutes, with only a screwdriver.

To get all the facts on these new, on-the-shelf, TRI-PLATE Modules, write today.

® Sanders Associates, Inc

Write for new bulletin on TRI-PLATE STRIP TRANSMISSION LINE MODULES

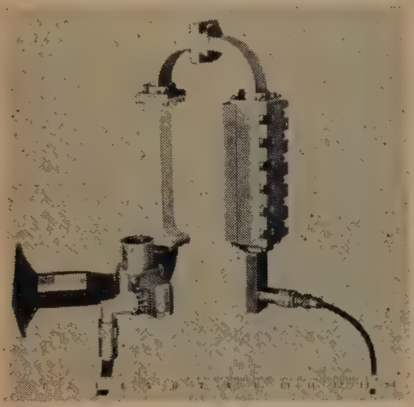
SANDERS ASSOCIATES, IN

Product Manager, Microwave Products Dept., NASHUA, NEW HAMPSHI

Circle Reader Service Card 33

New Products

NEW TESTING SYSTEM FOR CRYSTAL VIDEO RECEIVERS



A new team of microwave components that among other uses can provide an automatic testing system for crystal video receivers have been developed by American Electronic Laboratories, Inc. of Philadelphia.

The system incorporates a circularly polarized horn, high pass filter, and a band pass "Waffle Iron" filter and waveguide switch. The switch permits disconnecting the antenna, and connecting an impulse generator, thereby injecting an artificial signal to test the receiving equipment and crystal in particular.

The "Waffle Iron" filter was recently developed for the primary purpose of rejecting the second and third harmonics of the pass band frequencies. These filters present less than a ½ db insertion loss over the pass band and greater than 50 db suppression of the second harmonic. The high pass band filter section is used to improve the low frequency skirt characteristic. These filters are presently available in X, Ku, K and Ka bands as standard units and can be designed in custom bands on request.

The circularly polarized horns are made of cast aluminum and are available in the same bands as the filters. The horn presents an axial ratio of better than 1.5 to 1 and a VSWR better than 1.3:1 over most of their respective bands.

Circle Reader Service Card 101

— *mwj* —

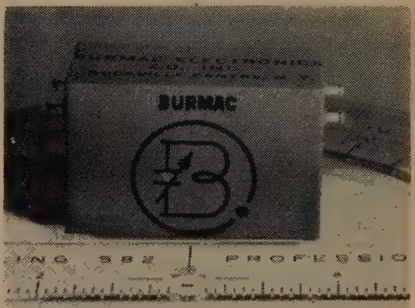
BIRD TERMALINE COAXIAL LOAD RESISTORS

Series 80-82 Termaline coaxial load resistors offered by Bird Electronic Corporation, Solon, Ohio, are especially designed for reflection-free terminations of flexible 50-ohm coaxial transmission lines. Their rugged construction, freedom from radiation and absence of any need for adjustment makes them useful as loads during adjustment, test, and alignment of transmitters operating in frequency ranges up to 4000 mc. Models in this series have a relatively constant impedance over the useful frequency range. Standard VSWR specification is 1.1 max to 1000 mc, and generally less than 1.2 to 4000 mc. Available power ratings are 20 to 2500 watts continuous in 6 models. Air convection cooling is used except for the 2500-watt unit which is water cooled. Increased rating, in the order of 25%, is possible with externally provided forced air cooling. Descriptive literature is available.

Circle Reader Service Card 102

— *mwj* —

NEW SOURCE OF KEEP-ALIVE POWER



A new source of keep-alive power for microwave TR switch tubes in ultra-miniature size, the model 859, is now available from the Burmac Electronics Co., Inc., Rockville Centre, N.Y. Additional features include light weight and extreme reliability.

The units' input impedance is sufficiently low to permit use of any required series resistor called for under TR tube specifications. Capacitors per MIL-6-25A, transformer per MIL-T-27A and silicon diodes are used. The 859 is resin cast, thermal shock resistant, and measures 1⅛" x 1⅛" x 1¾", while weighing less than 3 ounces. Output voltage and current are — 700 VDC minimum and 200 µamps, respectively. Ripple is 5% peak to peak maximum and line power 115 V at 400 cps.

Circle Reader Service Card 103

— *mwj* —

NEW MILLIMETER-WAVE CRYSTAL HOLDER

A new crystal holder designed to accept a specially developed millimeter-wave crystal is now available for mixing, detection, or frequency multiplication in the millimeter-wave band. The Model V-CH 1 crystal holder is designed to accept the new Philco 1N2792 crystal, developed for the 4-millimeter band. The crystal holder is available from TRG, Inc., Antenna and Microwave Department, Somerville, Mass.

The holder incorporates a tuning adjustment so that any of the Philco crystals can be matched to the line. The holder must be retuned at each frequency and for each new crystal. VSWR, when matched, is less than 2 for all crystals, and less than 1.5 for selected crystals.

Tolerances to the input section of waveguide leading to the crystal itself are maintained to a high precision, so that the holders can be used in balanced pairs wit balanced crystals in a mixer circuit.

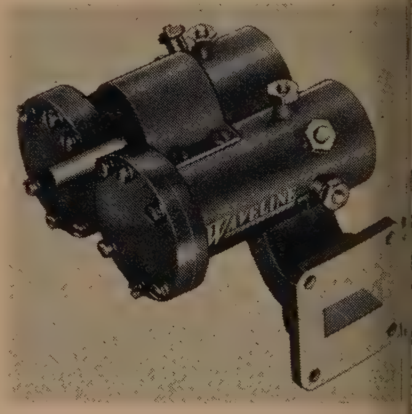
The silver-plated brass crystal holder approximately 2 inches in length, mat with RG 98/U waveguide and uses U 385/U connectors. The 2½ oz. unit sealed by means of an O-ring so that it ca be used in a pressurized system, up 30 psi. Output connector is a miniatu BNC or microdot.

A new illustrated catalogue with com plete specifications on the crystal hold and other new millimeter-wave comp nents and antennas is available from manufacturer.

Circle Reader Service Card 104

— *mwj* —

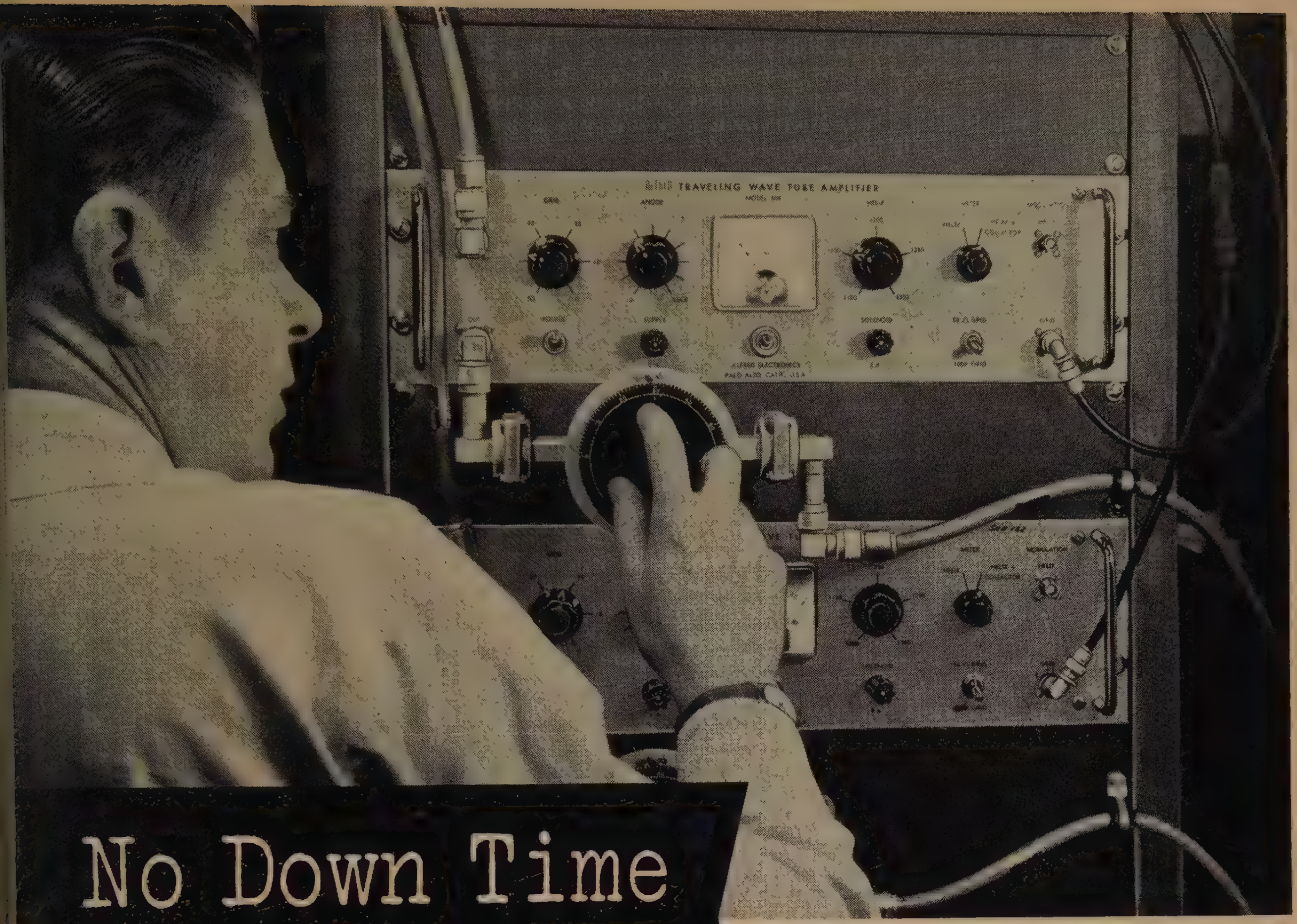
WAVEGUIDE FILTERS



Waveline, Inc. of Caldwell, New Jers is offering a line of microwave wavegui filters. Standard configurations are ava able for band pass, high pass, low pa band reject, and other types. Shown he is a tunable two section dual TE_{111} mo preselector filter designed for operation the 8500 to 9600 mc range. A 30 nominal bandwidth is provided at insertion loss of 1.8 db maximum and rejection of 55 db minimum at F_0 60 mc and 40 db minimum at F_0 — 60 m

Complete design, development, produ tion and testing services are outlined a four page brochure available on reque Various types of filters are pictured a described. An outline of electrical mechanical specifications to be submit with quotation requests is given.

Circle Reader Service Card 10



No Down Time Is Normal...

Alfred Electronics Model 504 Microwave Amplifiers, in use at Hughes Aircraft Co., Culver City, California

with ALFRED Microwave Amplifiers

ese Alfred TWT microwave amplifiers have seen con- uous service at Hughes for over 9 months. There has n practically no down time even for replacement of WT tubes. Used in the RF portion of a missile testing tem, the Alfred units provide high gain, wide band, response and low spurious modulation from 8 to 12.4 kmc. Hughes engineers praise the functional layout of the Model 504, its simple operation and reliable performance.

In short, Hughes finds the Alfred 504 Microwave Amplifiers good, sound, straightforward reliable instruments. We think you will too.

EY SPECIFICATIONS—ALFRED MICROWAVE AMPLIFIERS

	Model	Frequency Range kmc	Gain db (min)	Power Output (min)	Price
General Purpose Amplifiers for AM, Pulse and hase Modulation	505	1 to 2	30 db	10 mw	$1,550
	501	2 to 4			$1,390
	503	4 to 8			$1,490
	504	8 to 12.4			$1,490
	549	10.5 to 16			$3,550
Medium Power Amplifiers	5-6752	1 to 2	30 db	1 w	$2,290
	512	2 to 4	30 db	1 w Pulsed	$1,850
			20 db	100 mw CW	
	502	2 to 4	30 db	1 w	$1,390
	5-6868	2 to 4	30 db	10 w	$2,850
	506	{ 4 to 8 4.5 to 7.5 }	27 db	{ .5 w 1 w }	$2,290
	5-542	4 to 8	25 db	1 w	$3,190
	510	8 to 12.4	20 db	100 mw	$2,150
	509	8.2 to 11	27 db	.5 w	$3,150
	5-6996	8 to 9.6	30 db	10 w	$3,590
High Power Amplifiers	5-6826	2 to 4	30 db	1 kw pk	$4,850
Low and Medium Noise Figure Amplifiers	Amplifiers with low and medium noise figures are available either as packaged units or unitized for remote operation of TW tube and solenoid. Standard units provide coverage from .5 to 12.4 kmc with noise figures from 7 db up.				

MANY MODELS TO CHOOSE FROM

The 504 is just one model from the industry's most complete line of microwave amplifiers. For technical details and a demonstration arranged at your convenience, contact your nearby Alfred representative or write direct. Please address . . . Dept. 69.

ALFRED ELECTRONICS

897 COMMERCIAL STREET
PALO ALTO, CALIFORNIA

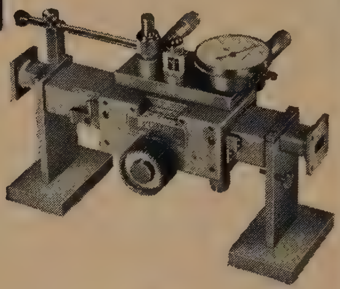
Circle Reader Service Card 34

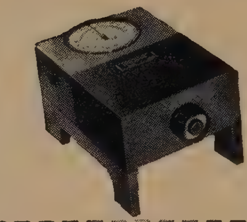
precision measurement demands

WAVELINE MICROWAVE

instruments

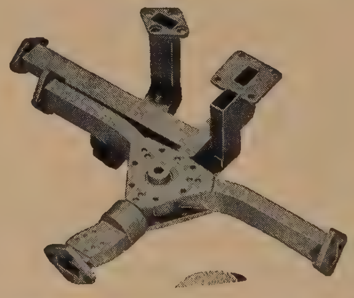
ATTENUATORS
SLOTTED LINES
WAVEGUIDE COUPLERS
TERMINATIONS
FREQUENCY METERS
PHASE SHIFTERS
DETECTOR MOUNTS
PRECISION TUNERS





and components

MIXERS
FILTERS
ANTENNAS
ROTARY JOINTS
DIRECTIONAL COUPLERS
WAVEGUIDE TEES
DETECTOR MOUNTS
WAVEGUIDE SWITCHES



The ninety page Waveline catalog describing over 600 instruments, includes complete technical data, charts, illustrations and engineering reports.

WAVELINE INC.
CALDWELL, NEW JERSEY

Phone CApital 6-9100
TWX Caldwell, N. J. 703

New Products

(*Continued from page 58*)

NEW TUNABLE WIDEBAND RF AMPLIFIER

Applied Research, Inc., Port Washington, N.Y. announces a compact, vacuum tube operated tunable amplifier, with self-contained power supply, which provides high gain, low noise, over a wide range of frequencies and bandwidths. The equipment is mounted on a standard 19-inch rack panel only 3½ inches in height. The center frequency is adjustable from the front of the panel. The unit is designated as model UH-2(AT).

Tunable center frequency ranges of as much as ± 10% of the nominal frequency, not to exceed 150 mc, are possible. The center frequency may be between 300 mc and 1000 mc. Representative noise figures ranging from 5 db at 400 mc to 8.5 db at 1000 mc are obtained by the use of co-planar low noise triodes. Only two stages are needed to realize an overall gain of 18 db. Nominal bandwidth of 10 mc is available.

Input and output impedances are standardized at 50 ohms, with VSWR of <1 at input, <1.75 at output.

Equipment normally operates from power supply input of 117 vac, 60 cps, 25w, may be obtained with other inputs.

Price in units of 1 to 5 is $1,150.00 with 10% discount for 6 or more. Delivery is 45 days after receipt of order.

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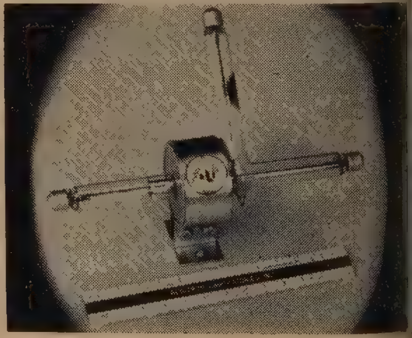
— *mwj* —

RESITRON HIGH-VACUUM RELAY

Resitron Laboratories, Inc., 2908 Nebraska Avenue, Santa Monica, California has added a new high voltage, high vacuum



relay to its existing line. The new unit Model 35 is capable of switching up 35 pkv, ac or dc in air and is ideally suited for switching high-powered radar pulse networks, dielectric testers, high voltage power supplies, x-ray apparatus, etc.

This standard model is supplied with 24v dc actuating coil. Actuating coils with other voltage requirements can be supplied in this model on special order.

Circle Reader Service Card 107

or original equipment, direct replacement

EC tubes with new doped-nickel cathode

Both tube series described here use NEC's new doped-nickel cathode core material. This 10-year development increases emission without raising operating temperature. Oxide evaporation rate is lower than any known core material. Operating data show tube life is extended up to 50%.

6R-P10

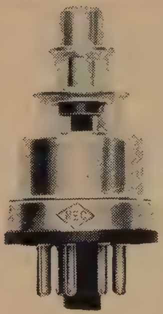
6R-R8

WIDE-BAND AMPLIFIER TUBES: Development began seven years ago with the 6R-R8, which was used in Japan's first microwave link. A modification, 6R-R8C, with very low distortion factor, is used in coaxial amplifiers. 6R-P10 Power Amplifier Pentode, with high mutual conductance and small capacitance, is designed for larger power output.

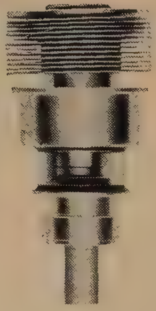
Type	Name	Cathode Rating		Screen and Plate Supply Voltage Eb (V) Ec2 (V)	Plate Current Ib (mA)	Trans-conductance Gm (μΩ)	Capacitances		Interchangeable Tubes
		Volts Ef (V)	Amp. If (A)				Input μμF	Output μμF	
6R-R8	Sharp-Cutoff Pentode	6.3	0.3	150	13	12,500	7.8	3.2	with WE 404A
6R-R8C	Sharp-Cutoff Pentode	6.3	0.3	150	13	12,500	7.3	3.2	with WE 404A
6R-P10	Power Amplifier Pentode	6.3	0.5	150	36	13,500	10.5	2.7	—

pe	Use	Cathode Rating		Maximum Plate Voltage Ev (V)	Maximum Plate Dissipation Pp (W)	Power Po (W)	Maximum Frequency f (MC)
		Voltage Ef (V)	Current If (A)				
22	Detector	6.3	0.75	150	—	—	1200
9A	Amplifier Oscillator (Continuous)	6.3	1.0	1000	100	15	2500
40	Amplifier Oscillator (Continuous)	6.3	0.75	500	4	0.75	3370
43	Amplifier Oscillator (Continuous & Pulse)	6.3	0.9	3500*	12	1.0	3370
61	Amplifier Oscillator (Continuous)	6.3	0.4	350	10	0.5	3700

* Pulse plate Voltage (eb)



2C40



2C39B

DISC-SEALED TRIODES: NEC designed the first disc-sealed tube in 1939, giving NEC many years of experience in the design and manufacture of this type of microwave tube. Each is a direct replacement under all circumstances for the corresponding type. The NEC tube will give longer life, an especially important advantage in repeater stations.

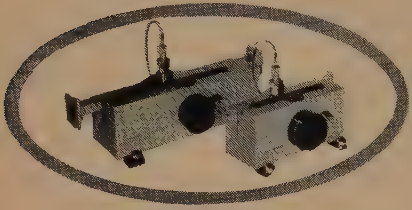
Please write for specifications sheets.

NEC *Nippon Electric Company Ltd.* Tokyo, Japan
COMPONENTS / SYSTEMS

Circle Reader Service Card 36

STANDING WAVE DETECTORS

—exceptionally accurate



You get the accuracy that results from perfect parallelism between slot and waveguide axis . . . between probe travel and waveguide axis. Only 30 seconds needed to equip a D-B slotted line to measure adjacent frequency bands. Range: 5.8 KMC to 140 KMC—covered by a *minimum* of units, to stretch your budget. Literature on request.

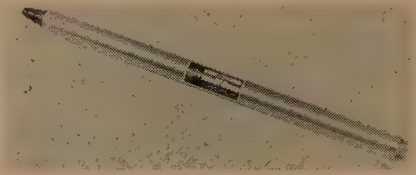
DE MORNAY BONARDI

DE MORNAY–BONARDI
780 SOUTH ARROYO PARKWAY • PASADENA, CALIF.

Circle Reader Service Card 37

AN ELECTROSTATIC FOCUSED TWT

Typical of the line of electrostatically focused, L-Band Amplifier Traveling Wave Tubes being manufactured by Huggins Laboratories of Sunnyvale, California, is the HA 27. This tube operates on a frequency range of 1.0 to 2.0 kmc with a small signal gain of 30 db min., and a saturation power output of 7 dbm min. Substantial savings in weight and size have been effected in the HA 27 which measures 1″ in diameter and 16″ in length. Net weight is 1.0 lb. of unusual rugged construction the HA 27 meets the requirements of military specifications in operating temperatures, vibration and shock performance.



No magnetic structure either solenoid or permanent magnet is needed by the HA 27.

Circle Reader Service Card 108

— *mwj* —

WR-51 TEST EQUIPMENT

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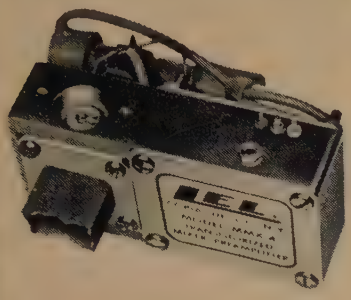

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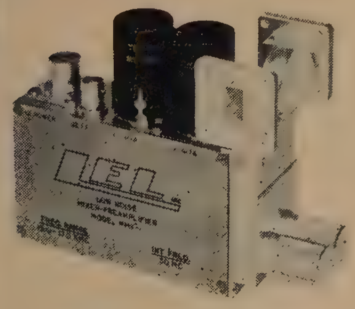

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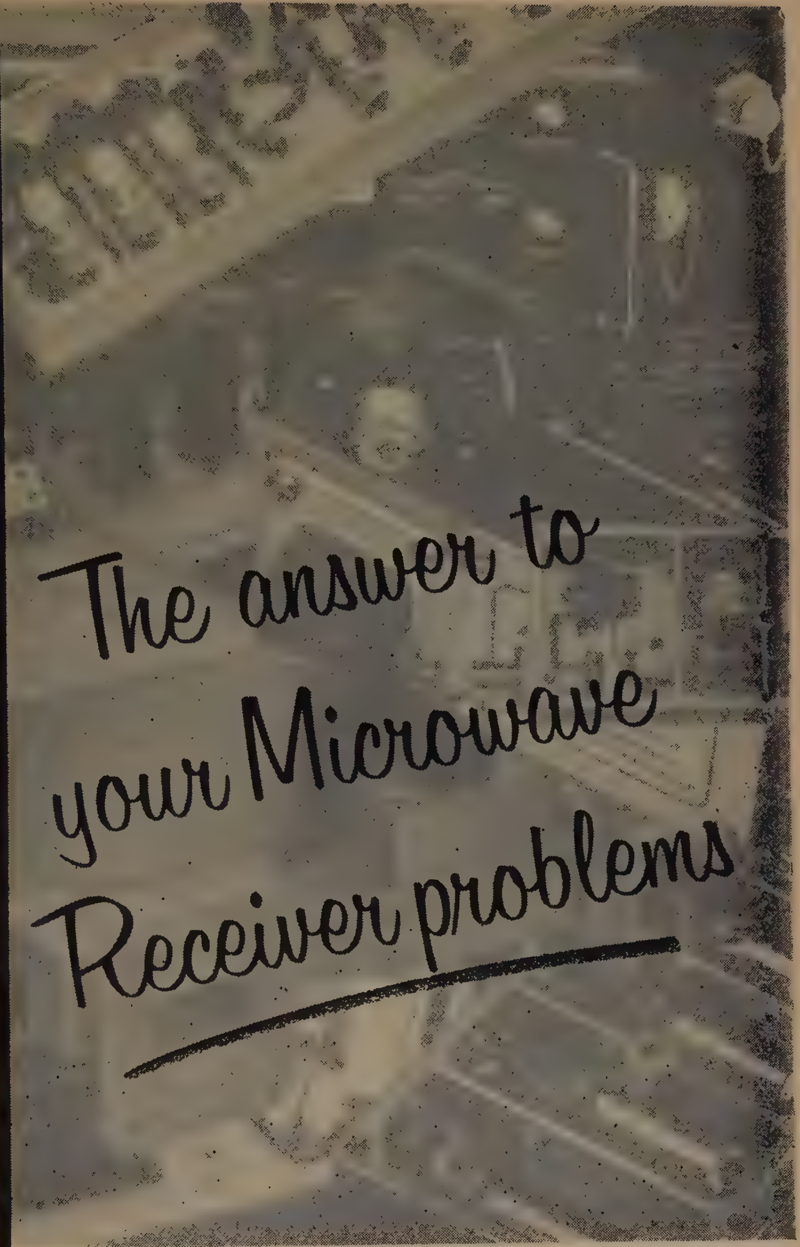

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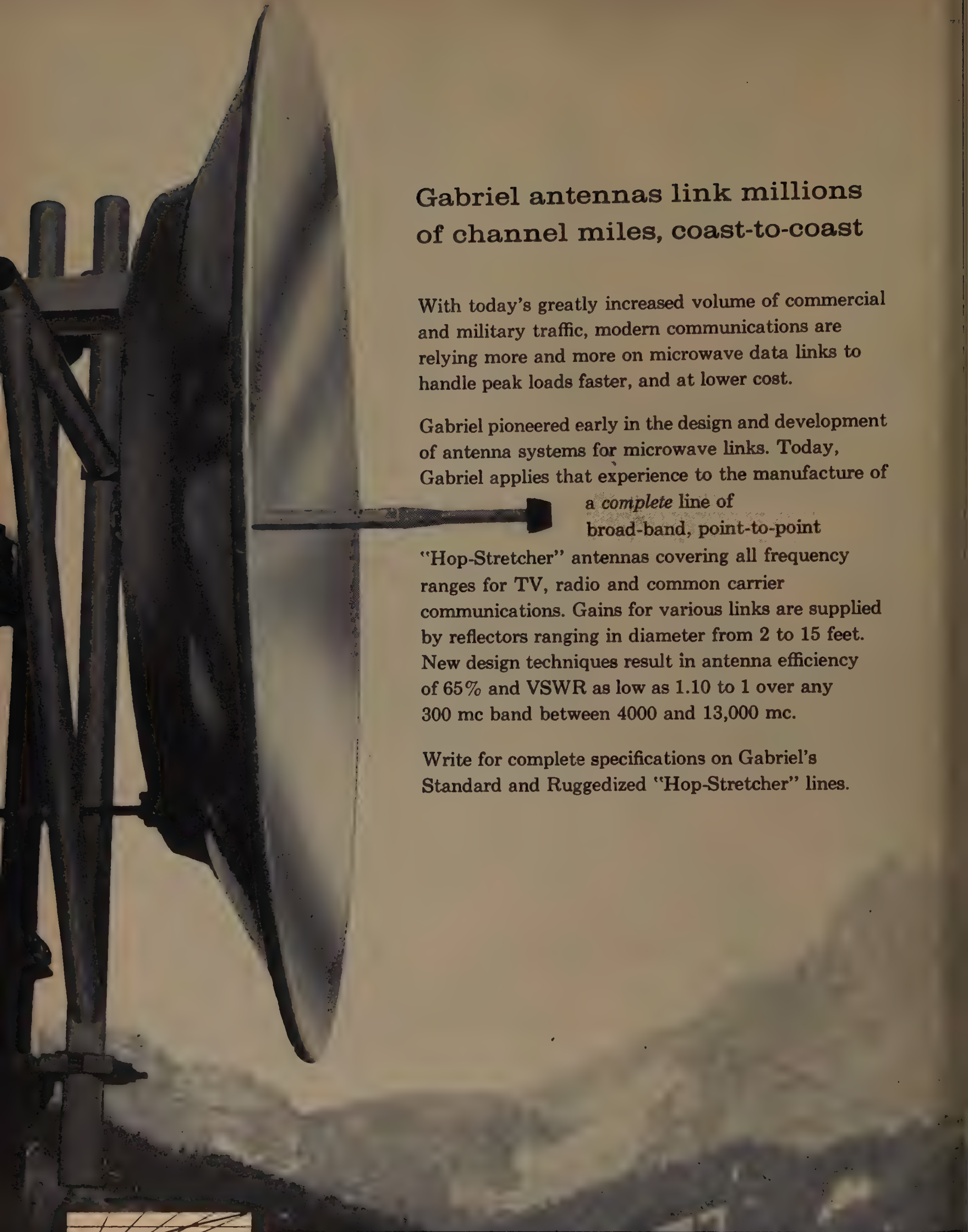

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U.S. NAVAL RESEARCH LABORATORY

WASHINGTON, D.C.

PART II

For about two decades after the Naval Research Lab- tory was established in 1923, approximately nine- ths of its scientific work was in the field of elec- nics. Because of the gradual expansion of investiga- ns in a dozen or so of the physical and engineering nces, electronics alone now accounts for about one- f of the Laboratory's basic and applied research and elopment programs. What NRL has accomplished is doing in the way of microwave electronics is in e measure the outgrowth of pioneering and fruitful arch directed toward the application of higher and her electromagnetic frequencies to problems of Navy rest.

Getting the Laboratory started with high-frequency o investigations was due primarily to Dr. A. H. lor, who for many years was Superintendent of the io Division, and Mr. L. C. Young, an associate, who ow a consultant in the Radio Division. In Novem- 1923 these two original members of the Laboratory started investigating radio frequencies of 2000 kc upward, in spite of the fact that existing theories cated that such frequencies would be of no practical for long-range communication. Under these cir- stances, the Laboratory was faced with the task of ving to the Navy Communication Service and, in- ctly, to industry, the feasibility of high-frequency o.

ome of the key proofs which helped to convince the tics:

A 50-watt, high-frequency transmitter at NRL which nitted better communication to Balboa (in the Canal e) on a midsummer day than the Navy's 250-kilo- , low-frequency transmitter at Annapolis, Maryland.

A mobile, high-frequency transmitter and receiver. alled on the rigid airship *Shenandoah,* it provided inuous communication with NRL during the airship's t across the continent and back.

Progressive improvements in frequency stability and ision frequency control. Out of this latter work, came world's first high-power, crystal-controlled, high-fre- ncy transmitter, which for a long time handled nightly communication traffic from the Navy Department in hington to the American Embassy in London. A sim- transmitter, after NRL modifications which enabled handle 400-microsecond pulses, was used in 1925 he Carnegie Institute of Washington to obtain the radio-pulse measurement of the vertical height of the sphere.

Discovery of the "skip-distance effect," described in Physical Review (1926) by Hulbert and Taylor. This lutionized prior thinking on how radio waves travel and laid the foundation for modern wave-propagation theory.

5. The Laboratory did important work in the embryonic and subsequent stages of radio detection and ranging, now known as radar. Summarized in Table I are the principal contributions of Laboratory scientists to radar development prior to "Pearl Harbor Day" (December 7, 1941).

Today there are about twelve groups (branches and sections) of Laboratory scientists at work on basic and applied research and development projects which are geared to the discovery of new principles, techniques, and applications of the microwave art. Some of the projects are devoted to current problems, while others are long range in nature and are conducted in anticipation of the Navy's future needs.

NRL's microwave research spectrum is rather broad and is subject to change, of course, as conditions may warrant. There are relatively broad programs on radar, electronic countermeasures, counter-countermeasures, identification of friend or foe, communications, materials, radio astronomy, components, devices, systems, and so on. A few problems in the broad program have been selected for discussion here to illustrate in part the kinds of microwave research performed at NRL by different groups and why.

Propagation Studies

Transoceanic communication at microwave frequencies is the ultimate goal of NRL efforts to obtain fine-scale correlations between characteristics of tropospheric-scatter signals and meteorological parameters (e.g., refractive index). It was in 1945 that Laboratory scientists, while studying surface-duct propagation, discovered the tropospheric-scatter propagation phenomenon. Airborne radiometeorological measurements made at intervals since 1955 have shown the existence of "height gain," that is, the peaking of the signal at the atmospheric inversion temperature layer, which is found over all oceans in the trade-wind latitudes. This mechanism indicates the existence of propagation ducts, at altitudes of 5000 to 7000 feet, which are produced by trade-wind temperature inversion. A recent experimental program, conducted jointly by NRL and the Air Force Cambridge Research Center, has proved conclusively that there exists, over a considerable distance in the South Atlantic trade-winds area between the coasts of South America and Africa, an elevated transoceanic atmospheric duct capable of trapping and propagating radio waves at low loss.

In consonance with the rapidly emerging era of space-flight vehicles is an NRL program for studying the effects of rocket-exhaust flames on the propagation of microwave

ircle Reader Service Card 41

TABLE I

Chronicle of Radio Detection at NRL

1922	Ship near Alexandria, Va., approaching Washington, D.C. detected by Doppler beat at a range of about 3 miles (by Taylor and Young, later to join NRL)
1925	First use of radio pulses (400 microseconds long) to measure the vertical height of the ionosphere
1930	Airplane in flight detected by continuous-wave radio
1932	Project established at NRL by BuShips (then BuEng) for "location of enemy ships and aircraft." Complete plans for an early warning system turned over to Army
1934	Use of pulse radar suggested and work started on a pulse system. Continuous-wave radio detection system demonstrated to members of Congress. Workable pulse transmitter and receiver built and tested.
1936	Radar systems successfully operated at 28 mc, 80 mc and 200 mc, with transmitter-receiver duplexing system for common antenna working on 80 mc and 200 mc. Small aircraft spotted at 40 miles with strong echo signals.
1937	Tests of 200-mc radar at sea on *USS Leary*
1939	Model XAF 200-mc radar tested on *USS New York.* Aircraft tracked to 110 miles with uncertainty of 1/10 mile in range and 1 degree in bearing. Shell splashes spotted and shells tracked in flight. Radar navigation and IFF demonstrated. Development of plan position indicator (PPI) started. Contracts let for commercial production of XAF, renamed CXAM.
1940	U.S. compared notes with Great Britain; gave duplexer technique to British and received the cavity magnetron
1941	Nineteen NRL model CXAM radars installed o major ships of the Fleet

signals. These signals, when employed in tracking, detection, and guidance of missiles, might be distorted or attenuated by the ionization characteristics of the rocket-exhaust environment. In fact, the need for definite knowledge on ionization associated with rocket flames furnished the initial impetus for the development of microwave probes for studying this problem.

Microwave Reflections from the Moon

Studies of lunar-reflected signals, transmitted by NRL high-power pulse radars, have been conducted at this Laboratory since 1951. These studies, which have been carried out at progressively higher frequencies, have yielded data which are of interest in the fields of radio communications, radio propagation, and astronomy.

Measurements made at 198 mc indicated that the moon was not as rough a reflecting surface as had been thought but was sufficiently smooth to produce almost specular reflections. Careful examination of A-scope radar traces has shown that more than 50 percent of the echo power is returned in the first 50 microseconds after the leading edge of a short-incident pulse contacts the moon. That part of the echo containing the first 50 percent of the reflected power comes from the first five miles of "depth," or a circle 210 miles in diameter, which is almost exactly one tenth the diameter of the moon; thus, one half the power in the echo is confined to a small "highlight" approximately three minutes of arc in diameter. These results posed interesting astronomical possibilities, such as refined measurements of the earth-moon geometry, and suggested the use of wide-band communication signals in a circuit employing the moon as a passive relay. The latter was versified by practical experiments in 1954. At that time a voice signal launched at the moon returned 2.648 seconds later with less distortion than that produced in an overseas radio telephone. Subsequently, the earth-moon path was tried out with receivers set up in California and, later, in Hawaii. Continuous-wave signals and teletypewriter signals passed over the lunar circuit were received with no detectable loss of intelligence.

In 1956, a program was started at NRL to determine (a) the feasibility of observing echoes from the moon with a radar operating at a frequency of 2860 mc using a 2-microsecond pulse and (b) how accurately the radar distance to the moon could be measured. Results of this program in February 1957 demonstrated that it was feasible to measure radar range to the moon with a high degree of accuracy. By using the measured distances it was possible to determine a better value for the earth's equatorial radius and to derive the mean equatorial par-allax of the moon.

Radar Tracking

One of the largest of microwave groups at NRL is devoting a major part of its effort toward advancing the state of the art of precision radar tracking. Improve acquisition, resolution, tracking accuracy, target identi-fication, and counter-countermeasure techniques are som of the specific goals. Of fundamental importance are th studies made of the microwave-radar characteristics o various targets to determine echo noise characteristics depolarizing effects, and effective radar areas. A com-panion program, under which the radar characteristics o all classes of Navy ships, aircraft, sea clutter, and groun clutter have been measured, has produced the most com-plete set of data available anywhere. The results of thes studies lead to new concepts and techiques for trackin improvement.

A variety of projects, ranging from new microwav techniques and components to experimental systems, ar included in the radar tracking research program. Advance monopulse, multimode, and polarization techniques ar being developed. Component developments encompas new monopulse feeds, special ferrite devices, multimod junctions, etc. The new trimode turnstile junction ha recently been applied to a novel instantaneous microwav polarimeter for directly observing signal polarization.

ew airborne sea-surface profiler under development employs a low-power X-band radar which is frequency modulated over a wide band at a 2-mc rate to achieve high nge resolution. And just getting under way is an apied research project to exploit microwave resonance henomena.

icrowave Tubes, Antennas, and Components

One of the earliest postwar contributions of the Labatory toward the development of tubes for millimeter aves was the invention of the electron-wave tube, in 48, which provided a novel method of generating and nplifying microwave energy. The method is based on e space-charge interaction of electron streams at differt velocities and requires no passive circuit in the nplifying region of the tube. In Laboratory tests of th the single- and two-beam type of electron-wave tubes, ectronic gains of the order of 80 db at 3000 mc and banddths of over 30 percent were observed.

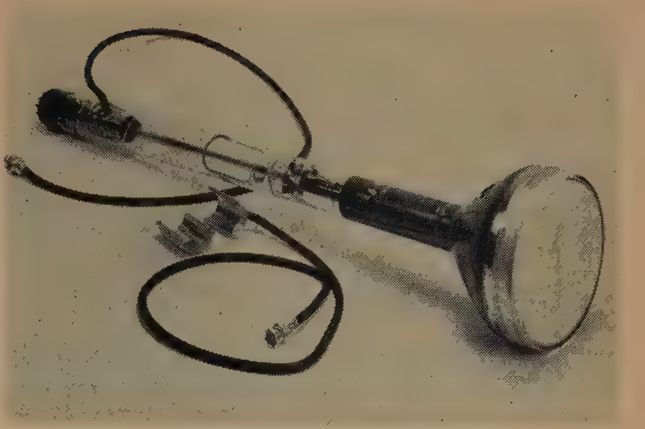
A more recent contribution resulted from the NRLonsored development of the Wamoscope, which performs three functions in one envelope: amplification, tection, and visual presentation. The idea of the amoscope was conceived at NRL as a method of passing display difficulties encountered with shorter d shorter pulses and increasing bandwidths beyond 0 mc. The Wamoscope was developed under contract NRL by Sylvania. Sensitivities in the order of microperes per microwatt are typical, which allow visual esentation of signals as low as —40 dbm.

Some of the current investigations in uhf tube research lude: (1) studies of a monotron, which employs the M_{011} mode of a cylindrical resonator, as a promising rce of coherent millimeter waves; (2) studies of the rces of excessive noise in conventional microwave tubes agnetrons and M-type carcinotrons) which use crossed ctric and magnetic fields; and (3) studies of a novel e of magnetron which, hopefully, might be scaled to erate at a wavelength of 1 millimeter.

Microwave antenna and components research at the oratory falls broadly into two classes. The first class concerned with designs to be used in specific radar tems, and the work is closely tied in with the system uirements. In the second category, the research is ned at the discovery of general design principles which ld be used in the development of a variety of antennas.

One of the antenna design problems which has been died extensively is that of scanning. This problem has to an investigation of a number of reflectors and ses with which scanning is achieved by movement of uitable primary radiating element. Optical techniques l designs borrowed for this purpose were suitably modd to make them effective at microwave frequencies. nificant developments in a number of so-called widele optical antenna systems have resulted from this gram. These include the Luneberg, Schmidt, and bial lenses and the Mangin Mirror. A design technique evolved for producing shaped beams by means of quasi-point source and an appropriate reflector.

Current developments include a study of progressiveve antenna arrays and a study of electromechanical nniques for scanning large two-dimensional arrays. The er involves the use of spiral radiating elements so t phasing can be achieved by rotating the individual nents. These elements may be fed by transmission lines or by an incident field transmitted from a simple radiating element. Also among current work are investigations on fully electrically scanned arrays.



Experimental Wamoscope tube.

A small group was formed in 1954 to do research on semiconductor devices, with particular emphasis to be placed on devices of military interest as opposed to those of wide commercial interest. The point-contact microwave mixer diode and the point-contact microwave low-level detector were among the first devices to be studied, and, later, the high-frequency properties of pn junctions received some attention. High- and low-power microwave facilities were set up, as well as facilities for the growth of heavily doped single crystals of silicon and germanium and the fabrication of devices. Recently, work has been done on the characterization and measurement of microwave negative-resistance amplifiers.

There follows a brief description of some of the successful projects, details of which have been published or will be published: (a) A study of the mixing properties of a nonideal microwave mixer diode; (b) a pn-junction model of the commercial germanium microwave mixer diode; (c) some measurements on a microwave mixer which exhibited negative-resistance effects and gain; (d) X-band noise-figure and conversion-loss measurements on GaAs microwave diodes; and (e) the high-frequency properties of certain pn-junction diodes.

Problems receiving attention at this time include the improvement by a large factor of the sensitivity of the point-contact, microwave, low-level detector; high-level microwave detection (for TRF microwave receivers); small-signal theory of nonideal pn junctions; novel methods of detecting microwaves; and a new way of measuring coaxial line impedance.

Microwave Properties and Applications of Materials

The U.S. Naval Research Laboratory was one of the first in the country to enter the microwave ferrite field. This was prompted by the appearance of the Luhrs switch, named after its inventor, C. H. Luhrs (not of NRL). By means of this switch the transmission of microwave energy in a waveguide system could be controlled simply by energizing a solenoid which was wound on a section of round waveguide containing a ferrite cylinder along its axis. The operation of this switch was based on a principle of optics discovered by Faraday years before and known as the Faraday rotation principle. It was recognized at once that by means of some simple modifications the switch could be converted into a phase shifter whereby

Dr. J. I. Bohnert, Superintendent of the Electronics Division, receives the "Award of Merit for Group Achievement" from Capt. P. H. Horn, former Director of NRL. This Award was granted in recognition of the achievements of the Ferrite Research Section headed by Dr. M. L. Kales. Earlier recognition of the work of this group was accorded when Messrs. H. N. Chait and N. G. Sakiotis were awarded the first Microwave Prize by the Institute of Radio Engineers for a published paper which presented the results obtained by research in the microwave ferrite field.

the phase of the output could be controlled electronically. Here in principle was a basic element which could be employed in the design of an inertialess scanning antenna.

Because of the importance of inertialess scanning antennas in radar, a research program was undertaken which was aimed at obtaining improved ferrite materials and finding new ways of using existing ones. The latter involved an award-winning theoretical and experimental study of propagation in various waveguide configurations containing magnetized ferrite media. One of the most fruitful and far-reaching discoveries which evolved from this program was a principle whereby nonreciprocal propagation could be obtained in rectangular and other waveguides. Unlike some earlier ferrite devices, this principle was not based on the Faraday rotation. It was shown that both phase velocity and attenuation could be made nonreciprocal. The former made possible a rectangular waveguide version of the circulator, and the latter led to the resonance isolator. Both of these devices are now of great importance in radar applications and as tools in laboratory research. Other microwave ferrite devices which originated at this Laboratory were a magnetometer, a turnstile circulator which made use of the Faraday rotation in a new way, a reflection type of circulator based on selective reflection or transmission of circularly polarized modes, a Y-circulator which made use of a nonreciprocal field displacement, a very broadband rotator, and several birefringent devices of both the reciprocal and nonreciprocal variety. In addition, a great deal of information about propagation in magnetized ferrites was obtained. This included the discovery that the deterioration in the performance of certain ferrite devices was caused primarily by nonlinear effects at high power levels, rather than by heating due to power dissipation, as had been commonly supposed.

Ferrite phase shifters for scanning antennas pose the most stringent requirements of the microwave ferrite devices. Temperature- and frequency-dependent hysteresis effects, nonlinear effects, attenuation, and various other considerations are involved in the design of phase shifters. These and other aspects of microwave ferrite research occupy the attention of scientists at the U.S. Naval Research Laboratory.

Three of the research programs conducted by one of th major solid-state groups at NRL are directed toward th development of electromagnetic materials and material systems for special applications, such as dielectric lense microwave absorbers, insulators, and insulating system One is devoted to studies of the complex magnetic permeability-dielectric constant and the reflection coefficient c materials over a wide range of frequencies, temperature and compositions. The second is concerned with the factors which influence the behavior of insulators and insulating systems, such as thermal aging, fatigue and breakdown, repetitive high-voltage surges, and radiation effect work also is in progress on the development of instrumentation for the prediction of insulation life. The thir is concerned with the construction of solid-state electroni devices and the development of instrumentation basic t the detection, indication, or display, of solid-state phenomena.

Several years ago the electromagnetic materials grou developed two new broadband absorbers which remove a long-standing obstacle to the construction of microwav anechoic chambers. Both materials were made by impregnating a commercially available mat of curled anima hair with a mixture of conducting carbon black an neoprene rubber to provide for dissipation of r-f energ The commercial production of material for and the construction of anechoic chambers has grown into a sizeabl industry.

The requirement on dummy loads (artificial antennas for testing or adjusting radar sets becomes more stringen as the output power of present-day radars continues t increase. As early as 1951, NRL scientists experimente with the idea of applying a layer of high-loss, ferromagnetic material to the walls of a waveguide to absorb microwave energy and dissipate it in the form of heat. Thi sheets of neoprene loaded with carbonyl iron particle were applied to the interior waveguide walls with rubbe cement. Although the temperature limit was only abou 150° C, the overall efficiency encouraged further development in absorbent materials and methods of application As a result of this research, NRL scientists have produce various prototype dummy loads which utilize high-los ferromagnetic oxides in a silicone resin binder as th dissipative element. Among these are models for operatio at X-band, S-band, and L-band and the relatively lo frequency of 425 mc.

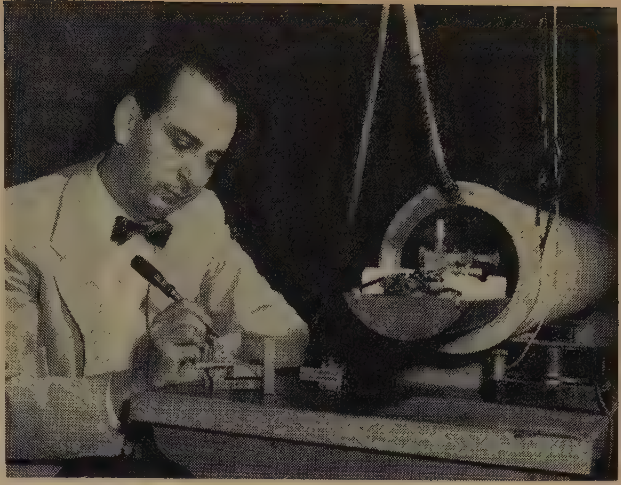
One of the most recent designs is a finned, L-ban waveguide load which weighs only 63 pounds (including the 5 pounds of absorbent material). Durin furnace trials at NRL, the coating survived a life te of 500 hours at 350° C. Adhesion of the absorbing material to the waveguide walls was not destroyed, eve though, at one point, the temperature of the load reache 390° C. Rough measurements of the temperature on th inside surface of the waveguide showed that the temperature gradient from the inside to the outside of the loa wall was less than 10° C, even for the maximum thickne of absorbent material used. In subsequent performanc tests, the load was able to dissipate a power input of 1 kilowatts, and the overall efficiency of heat distributio at this power level was 73 percent. These excellent performance characteristics insure an ideal dummy load fo radars operating at L-band frequencies.

Microwave methods have been used at NRL as part of
program directed toward understanding the basic char-
cteristics of ferromagnetic and ferrimagnetic substances.
ecent work in this field included microwave resonance
udies of relaxation processes and magnetocrystalline
nisotropy in single crystals of ferrites. A particularly
nteresting and unexpected result is the discovery that in
least one ferrite the disordered arrangement of the
rvation of exchange effects in ferromagnetic resonance.

Among the earlier results obtained in this field at NRL,
vo achievements may be singled out. One concerns the
pectrum of the complex initial permeability of sintered
rrites. On the basis of measurements extending from
ro frequency through the microwave range, it was
und that in several ferrites this spectrum contains not
st one but two or more regions of anamalous dispersion
d absorption. Since it proved possible to identify these
gions as arising from domain wall displacements as well
from domain rotations, this work provided the first
idence for the existence of domain wall inertia. The
her noteworthy achievement concerns the mechanism
sponsible for the nature of the microwave resonance
e in a ferromagnetic metal. By use of an alloy char-
terized by a magnetocrystalline anisotropy of nearly
ro, it was shown that in both monocrystals and poly-
ystals the width and even the shape of the resonance
e can be accounted for in terms of a mechanism in-
lving the combined action of the skin effect and the
change effect. These experiments have been termed
pin-wave resonance," and they represent the first ob-
rvation of exchange effects in ferromagnetic resonance.

In April 1958, a ruby (Cr^{3+}) maser, designed and
ilt by Professor C. H. Townes and associates at Co-
mbia University, was installed in NRL's 50-foot radio
escope to observe the extremely weak radio waves
m other planets, distant galaxies in collision, and
uds of ionized hydrogen gas between stars. The maser
s used as an r-f preamplifier in a radiometer sensitive
a frequency range of 8700 mc to 10,100 mc. In the
st attempt to evaluate and use the antenna-maser-receiver
mbination, an input noise temperature of 86° K was
lized, which represented a twelvefold improvement over radiometer sensitivity without the maser. Of that value, 26° K resulted from noise entering the antenna; hence the effective receiver noise temperature was 60° K, which corresponds to a receiver noise figure of 0.8 db. The resulting improvement in radiometer sensitivity has already made it possible to observe directly with short integration time the very weak radiations from the planets Jupiter, Venus, and Mars, and from "radio stars" and other sources whose radiations are too weak to be detected directly without the maser.

RL scientists A. G. Sands and M. V. McDowell knife-cast a
romagnetic absorber on the inside wall of an L-band wave-
ide. This dummy load will dissipate 10 kilowatts of power
and tolerate temperatures up to 350° C.



Dr. G. T. Rado, head of the Magnetism Branch and recipient of the 1957 Pure Science Award of the NRL Branch of the Scientific Research Society of America, points to part of the apparatus designed for measuring the exchange interaction forces in ferromagnetic resonance.

Applications of the maser may be extended as a result of studies by solid-state physicists at NRL, who found that the maser can be operated at temperatures well above those of liquid helium (4° K). By using a 0.1-percent concentration of the paramagnetic impurity Cr^{3+} in a doughnut-shaped ruby crystal, NRL scientists were able to obtain maser action at the temperature of liquid nitrogen (77° K). The development of masers which operate at these higher temperatures is important in extending their use into new areas requiring low-noise amplifiers where liquid-helium cooling is either impractical, inconvenient, or both.

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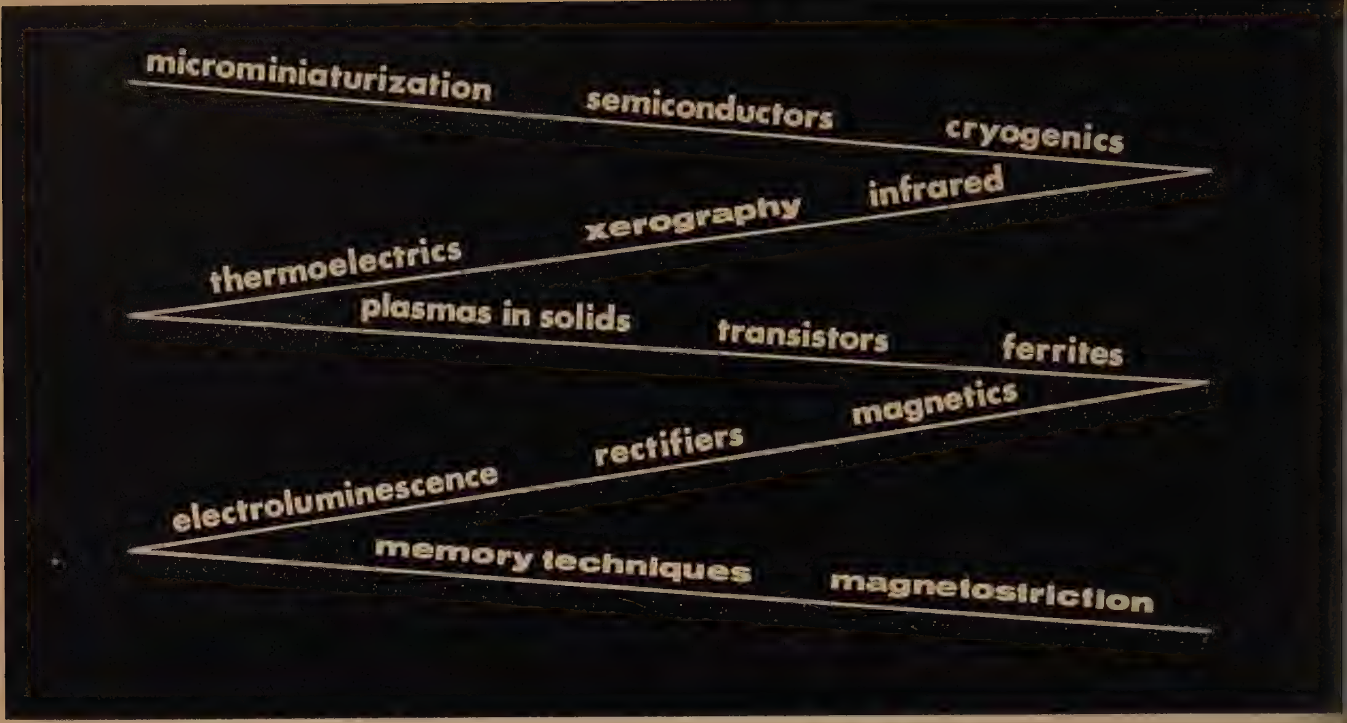

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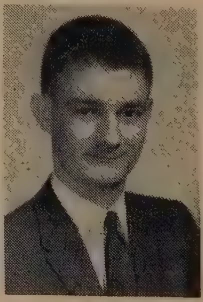

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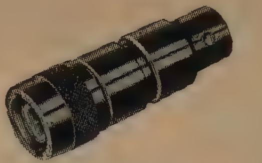
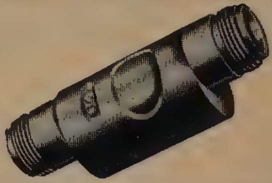
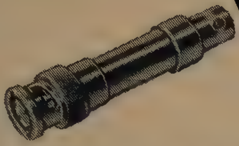
1.2 max. VSWR
2 and 15 watts



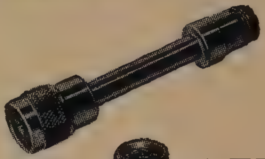
TURRET ATTENUATORS
DC to 2500 mc
0 to 30 db
1.25 max. VSWR
2¾″ overall



LOW PASS FILTERS
100 to 10,000 mc
1.2 max. VSWR
10 and 500 watts
Sharp cut-off

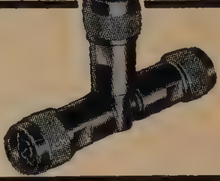


HIGH PASS FILTERS
200 to 6000 mc
1.6 max. VSWR
10 and 50 watts
Sharp cut-off

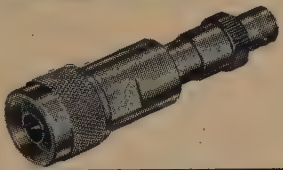


COAXIAL TERMINATIONS
DC to 13,000 mc
1.1 max. VSWR
2, 10, 150 watts
Fixed and sliding

POWER DIVIDERS
DC to 13,000 mc
2 to 6 outputs
Resistive—wide band
Reactive—min. loss

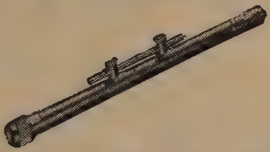


CRYSTAL MOUNTS
DC to 13,000 mc
Untuned, Fixed tuned;
Padded; Tripolar
High Sensitivity



STUB TUNERS
250 to 10,000 mc
Single stub
Double stub
Triple stub

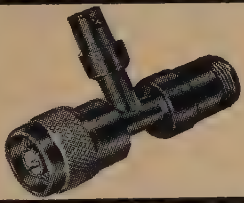
DOUBLE SLUG TUNERS
300 to 5000 mc
100 watts
Minimum size
Constant impedance



LINE STRETCHERS
DC to 5000 mc
1.2 max. VSWR
Constant impedance
Locking clamp

MONITOR TEES

Used to separate DC or video currents from an RF signal. Indispensable for monitoring helix intercept current in traveling wave tubes.



SIGNAL SAMPLERS

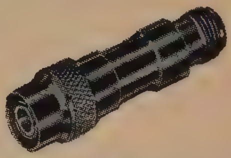
Used to monitor signals present in coaxial systems. Permits small signal to be taken from system without adding discontinuity. Coupling continuously adjustable.

DC SHORTS

Sections of constant impedance transmission line with built-in DC bypass, to ground low frequencies while allowing RF to pass unattenuated.

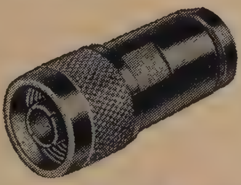
DC BLOCKS

Uniform lengths of constant impedance transmission line with DC blocking condenser in series with center conductor.



COAXIAL CONNECTORS
Now Available!

A Complete Line of UG and Special Coaxial Connectors.



NEW CATALOGS AVAILABLE
Coaxial Filters.
Catalog No. 9C.
Coaxial Terminations.
Catalog No. 9A.
Coaxial Attenuators.
Catalog No. 9B.

- **All MICROLAB products are available FROM STOCK with Type N, C, HN, BNC or TNC male or female connectors.**
- **Special values, connector combinations and other special design features at same low cost and quick delivery.**
- **Prototype or production quantities at lowest cost.**

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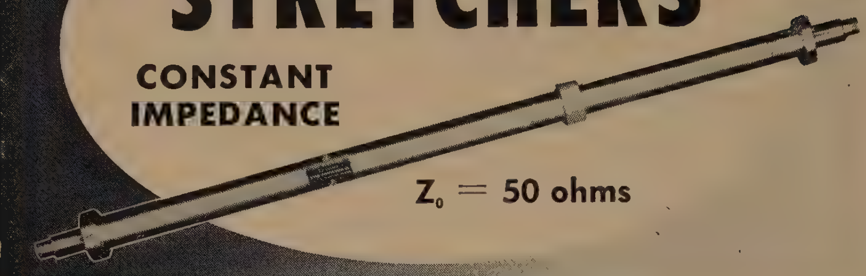
AMCI
LINE STRETCHERS
CONSTANT IMPEDANCE



- ***Rated at 0.5 kw cw at 1000 mc*** except as limited by connectors; constant impedance with low SWR.
- ***Rugged and dependable;*** electrically active portions are enclosed in and protected by an external case.
- ***Intended for long service;*** sliding contacts are made between solid coin silver tubes and solid sterling-silver fingers.
- ***Provided with a locking device*** and with positive stops at both ends of the line-stretcher travel.

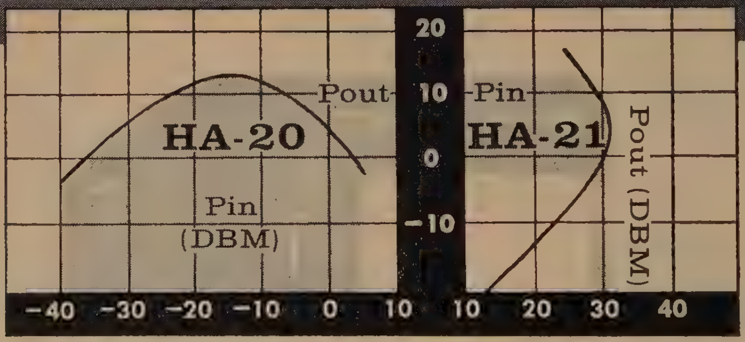
TYPE 3701B: 8″ extension } available with connectors to ⅞″ EIA
TYPE 3702B: 14″ extension } line, and Types N, HN or LC line.

Write for complete information on AMCI Line Stretchers

ANTENNA SYSTEMS – COMPONENTS – AIR NAVIGATION AIDS – INSTRUMENTS
AMCI ALFORD *Manufacturing Company*
299 ATLANTIC AVE., BOSTON, MASS.

Circle Reader Service Card 43

Cascade Operation of TWT's



Shown above are Huggins TWT's producing a power output range within ±1 DB over an input range of –40 to +5 DBM.

This pair of X-Band, light weight, PPM focused tubes is only one example of our ability to furnish TWT's to almost any specifications.

Please send for Engineering Note No. 6: "Cascading TWT's."

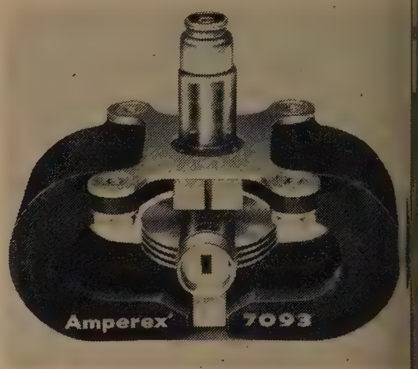
HUGGINS LABORATORIES
manufacture
development
engineering
design
research
HUGGINS LABORATORIES INC.
999 East Arques Avenue Sunnyvale, California REgent 6-9330

Circle Reader Service Card 44

New Products

NEW AMPEREX TYPE 7093 K-BAND MAGNETRON

Extremely short pulses of only 0.02 mi crosecond, with peak power output of mo than 25 kw, extremely small size an weight (4.2 lbs.) are the features of th new Amperex magnetron type 7093, d signed for service as a pulsed oscillat at a fixed frequency in the K-band b tween 34,512 and 35,208 mc.



Especially suited for use in high de nition, short range radar systems of u to five miles, the type 7093 makes possib a radar system that will have a reso tion of 4 meters (about 4.5 yards) range, and with proper antenna design display sharp enough actually to track pe ple walking or clearly outline airplane an ship shapes so that general types can identified. With a pulse length so shor a radar system incorporating the type 709 can have a minimum detection range only a few yards. So, if a radar is mounte on a ship, the shape of the ship itself wi be outlined on the radarscope.

Such radars using the type 7093 are em inently suited for use at airports, harbo and rivers and other heavy traffic location where extreme resolutions at short di tances is required.

At pulse durations of 0.02 microsecon the Rate of Rise of the Voltage Pulse i 600 kv/microsecond, with a Duty Fact of 0.0001, a Peak Anode Voltage of 13. 15 kv and Peak Anode Current of 12 amperes.

The type 7093 incorporates a Phili dispenser-type cathode which contribut to the tube's reliability and small siz A getter minimizes any tendency towa arcing, even when the magnetron is p into operation after a period of storage.

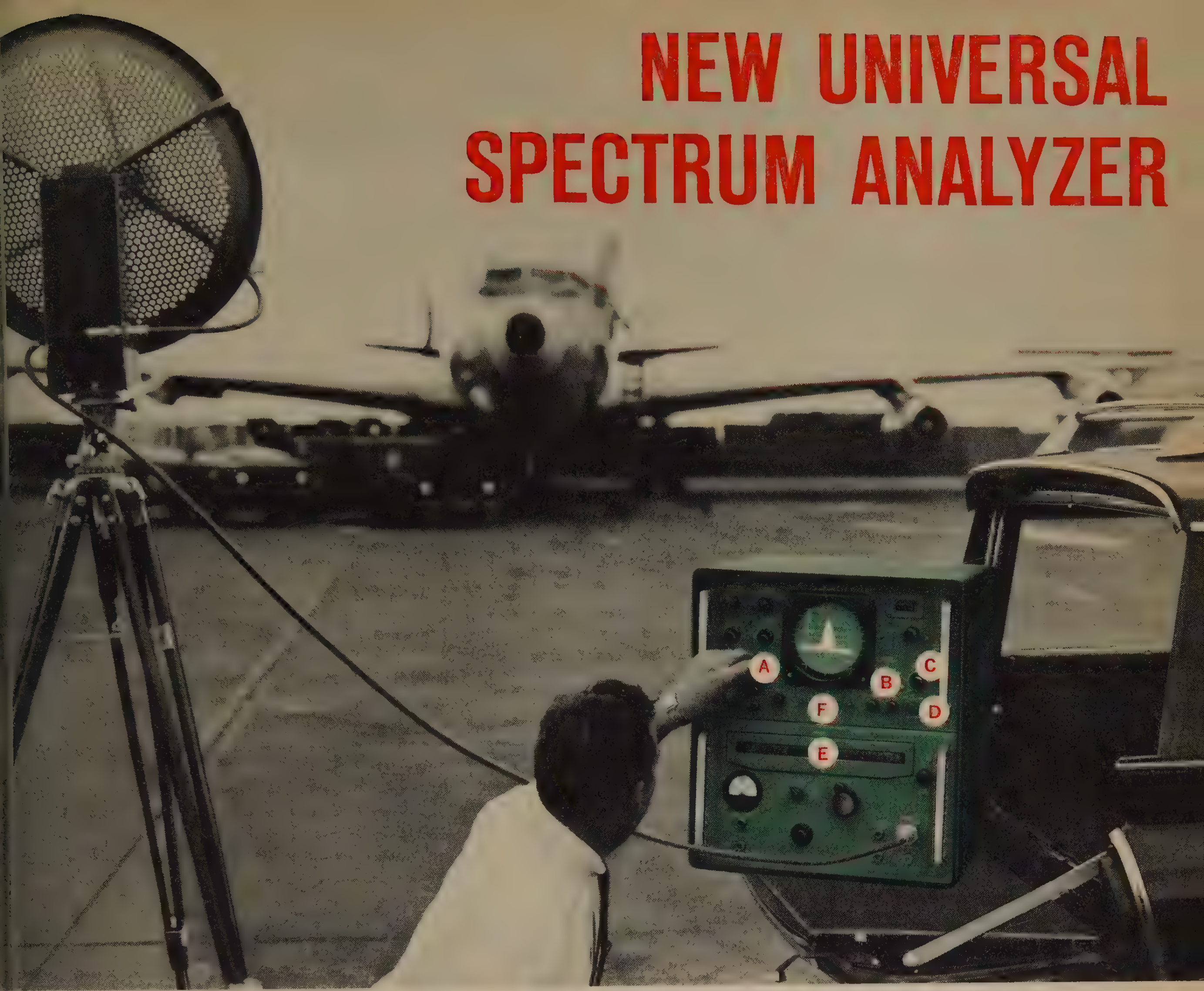
For normal operating conditions ano cooling by a low velocity airflow suffice When the anode temperature is kept bel 150° C, no additional cooling will be quired for the input terminals.

The Amperex type 7093 magnetron immediately available in sample and p production quantities.

Circle Reader Service Card 11

— *mwj* —

NEW UNIVERSAL SPECTRUM ANALYZER



ad Model SA-84W being used to make pulse analysis of radar aboard a Pan American Boeing 707, Jet Clipper®

MODEL SA-84W 10 to 44,000 MC in a single unit

URES:

r 80 mc dispersion

c to over 80 mc for
ow pulse analysis.

kc to 7 mc for wide
e analysis.

Ⓐ **Dual Resolution**

7 kc or 50 kc automatically set by dispersion control.

Ⓑ **Crystal controlled markers from 10 to 44,000 mc.**

Ⓒ **Provision for use with a multi-pulse spectrum decoder (Polarad Model SD-1)**

Ⓓ **Log-linear amplifiers**

Ⓔ **Expanded, direct-reading, slide rule dial.**

Ⓕ **Accurately calibrated IF attenuator**

Polarad Model SA-84W is the most accurate
ersal microwave analyzer to measure nearly all
ameters — Pulse, CW, FM, VSWR, antenna pat-
s, bandwidths and filter characteristics.

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ON ALL POLARAD
INSTRUMENTS

MAIL THIS CARD
for specifications.
Ask your nearest
Polarad representative (in the
Yellow Pages) for
a copy of "Notes
on Microwave
Measurements."

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RPORATION

34th Street, Long Island City 1, N. Y.

POLARAD ELECTRONICS CORPORATION:

M

Please send me information and specifications on:

☐ Model SA-84W Universal Spectrum Analyzer
☐ Model SD-1 Multi-Pulse Spectrum Selector
(see reverse side of page)

My application is____________________

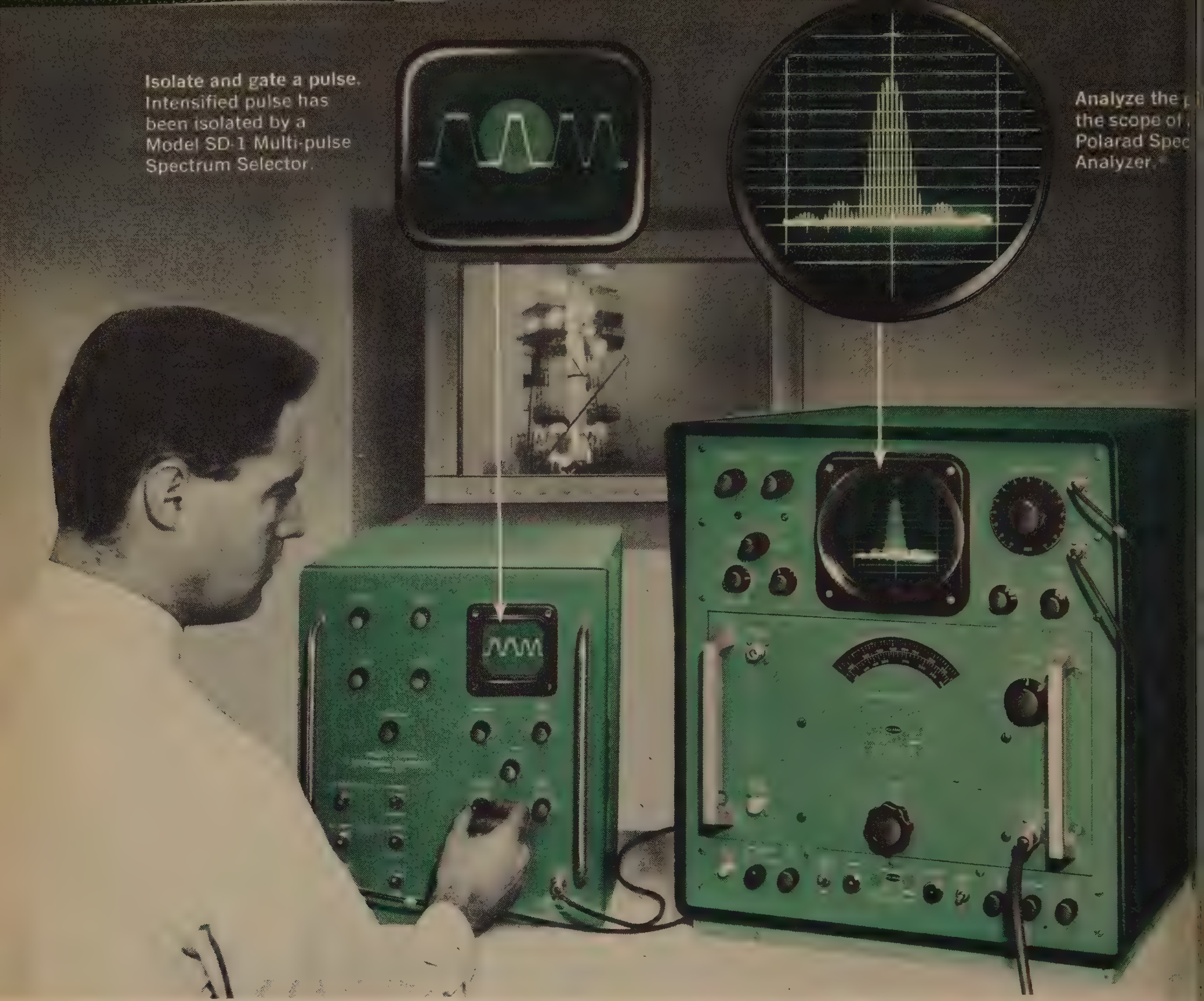
Name____________________

Title________________ Dept.__________

Company____________________

Address____________________

City________________ Zone______ State________



Isolate and gate a pulse.
Intensified pulse has
been isolated by a
Model SD-1 Multi-pulse
Spectrum Selector.

Analyze the
the scope of
Polarad Spec
Analyzer.*

COMPLEX SPECTRUM DECODING

10 to 44,000 mc.

Signal Analysis for Missiles, Telemetry, IFF, Beacons and Radar

The Polarad spectrum selector permits spectrum analysis a
coding of any selected pulse within a multiple pulse train. S
gate width and position can be controlled. Model SD-1 perm
selection and gating of a group of pulses up to 180 μsec. in
(Model SD-IX permits 350 μsec.)

Works with POLARAD Models TSA, TSA-S, TSA-W, SA-84 a
84W spectrum analyzers.

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ELECTRONICS
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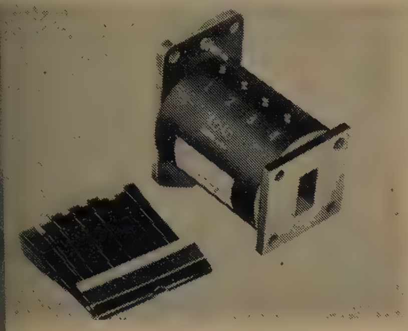
Representatives in principal cities.

KEARFOTT MICROWAVE ANNOUNCES NEW KU-BAND PHASE SHIFTER

A new Ku-Band Phase Shifter of excep-ionally small size and weight is being arketed by Kearfott Division, General recision Inc., Van Nuys, California, manufacturers of precision microwave compo-ents and systems.



Designated as Model No. 5106001, this ew small size phase shifter is ideal for e in confined areas where equipment ace is at a premium. A high degree of ase shift is offered and all ferro-mag-tic resonances are eliminated. The new it is temperature compensated and is t affected by environmental conditions. Outstanding features include: *Frequency nge* of 15-17 kmc (fo ± 10 mc); *Phase ift* is indicated at 112°; *Insertion Loss* 0.5 db max; Input *VSWR* is 1.12 max; *ak Power* is 3 kw. *Ambient temperature range* of −10° C to +100° C. *Length* is 2″.

Further information on the new Model 5106001 Ku-Band Phase Shifter is available on request.

Circle Reader Service Card 112

— *mwj* —

R.F. EQUIPMENT FOR PCM/FM AND FM/FM

The General Electronic Laboratories, Incorporated, are now delivering r-f equipment for PCM/FM and FM/FM telemetry in the frequency range of 1435-1535 mcs. This equipment consists of the following units:

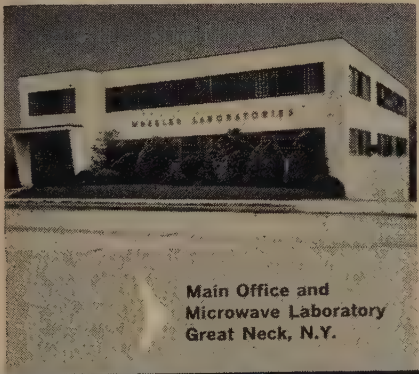
1. Circularly polarized receiving antenna, 2. Receiver, 3. Voice-modulation-separation chassis, 4. Transmitter, 5. Power Supply, 6. Transmitting Antenna.

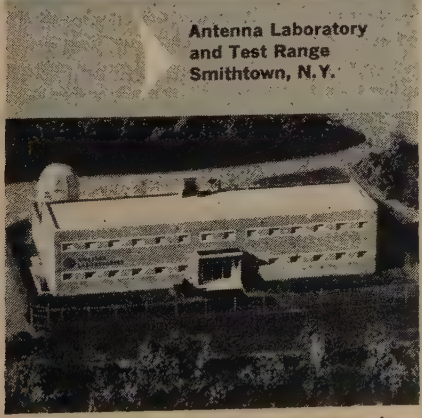
This equipment, capable of being used in the evaluation of missiles in flight as well as high performance aircraft, features a high order of center-frequency stability, power levels up to 20 watts, conductive cooling, and close conformance to the new IRIG specifications for both transmitting and receiving equipment operating in this frequency range.

Bulletin RX20 will be sent to those requesting it.

Circle Reader Service Card 113

— *mwj* —





WL

In the field of microwave engineering, Wheeler Laboratories occupies a unique position as an industrial laboratory devoted exclusively to consulting and development.

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WHEELER LABORATORIES, INC.

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As a service to many prominent laboratories and manufacturers, WL designs radar and communication antennas, waveguide components, and microwave assemblies. Your inquiries are invited.

Harold A. Wheeler
and
Engineering
Staff

WL

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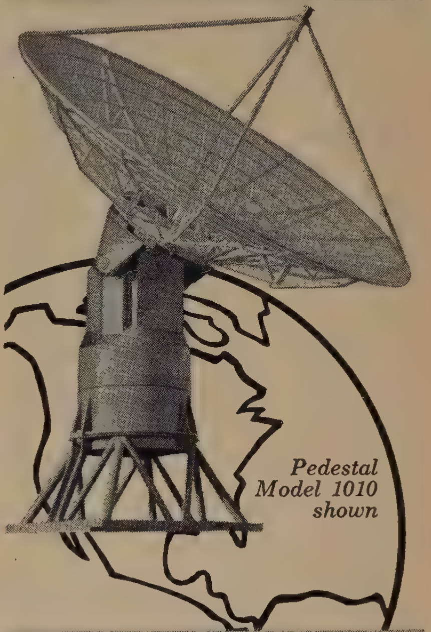

ANTENNAS *by* Ainslie CORPORATION

NOW — available from Ainslie Corporation, a new remote control positioning pedestal capable of handling our antennas up to 18 feet in diameter in frequencies from 100 to 10,000 mc. Modifications available for a variety of tracking applications. Whatever your antenna or reflector requirements may be, contact us at our new facilities.

Ainslie CORPORATION

531 Pond Street
South Braintree 85, Massachusetts

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NO TOOLING CHARGE

permanent tooling available . . .

C.W. Torngren Co., Inc., the largest manufacturer of spun aluminum parabolic reflector antennas in the country and originator of the exclusive Mecatorn® process, has machined and stocked permanent tooling for every diameter and focal length in popular use today. Reflectors can be Mecatorn® Powerspun from four inches to 12 feet in diameter.

No tooling charge is made for any standard Torngren reflector which is spun from 2S0 aluminum with rolled bead or straight flange. Backing and mounting structures can be furnished to your specifications at additional cost.

Since Torngren warehouses a full supply of aluminum circles, delivery is usually ONE WEEK F.O.B. Somerville, Mass., there is of course no charge for crating.

● Send for our latest price list and check the savings when you spin with Mecatorn®.

C. W. TORNGREN CO., Inc.
236 PEARL STREET
SOMERVILLE 45, MASS.

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CGS LABORATORIES NOW NAMED TRAK ELECTRONICS

Elton T. Barrett, President, CGS Laboratories, Inc., Wilton, Conn., announces that henceforth the company will carry on operations under the name of TRAK Electronics Company. The corporate name remains unchanged for the present, and the business will be conducted under the name TRAK Electronics Company, Division of CGS Laboratories, Inc.

In announcing the change, Mr. Barrett said: "The principal reasons for the change are the adoption of a name by another company similar to our corporate name, a desire to avoid the limitations implied by the word 'Laboratories,' and to facilitate promotion of the trade mark 'TRAK,' which already has wide acceptance in the trade."

Mr. Barrett also announced the appointment of Herman P. Taub, as Vice-President, Operations. Prior to this promotion, Mr. Taub was Operations Manager for the corporation.

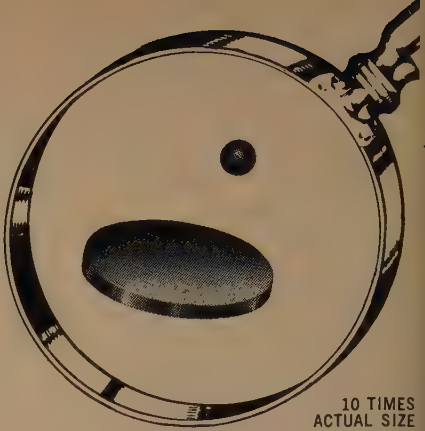
— *mwj* —

HAMRE APPOINTED GABRIEL SALES DIRECTOR

John B. Hamre has been appointed director of sales of the Gabriel Electronics Division, according to Stanton L. Yarbrough, president. Mr. Hamre formerly was divisional sales manager.

In his new position Mr. Hamre will direct the departmental operations in the Division's intensified sales program in liaison with engineering and manufacturing departments. He will have broad responsibility for the analysis and evaluation of sales markets for the division's products including point-to-point communication antennas; multi-channel rotary joints; antenna systems for ground-based and shipborne search and navigation radar; drone and missile control telemetry and tracking antennas. In this capacity Mr. Hamre will report directly to Mr. Yarbrough.

(*Continued on page 80*)



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SINGLE CRYSTAL
MAGNETIC GARNETS
HIGHLY POLISHED
SPHERES and DISCS
for
MICROWAVE THROUGH INFRA-RED REGION

FERRIMAGNETIC SINGLE CRYSTALS ARE NOW AVAILABLE FOR MICROWAVE AND MAGNETO-OPTICAL DEVICES.

Traveling wave masers
Magnetically tunable microwave filters
Ferrite parametric amplifiers
Light modulators
Other unexplored applications
Call or Write Department 21 for Data.

MICROWAVE
CHEMICALS LABORATORY, INC.
282 SEVENTH AVE. — NEW YORK 1, N. Y.

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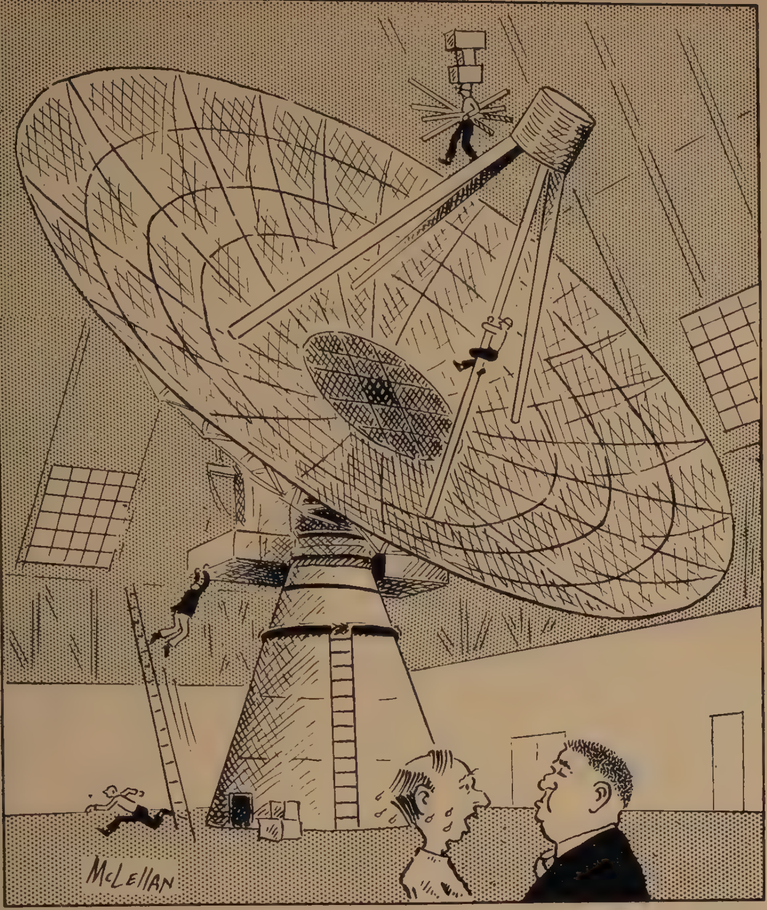

"Now let's have some of your great ideas on how to get this thing out of here!"

Waveguide
specialists in close tolerance
Bending and Forming

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PILGRIM 8-4700

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This is the most accurate, trouble-free
LEAK DETECTOR
you can buy

fast...simple...safe

- **Quick and Easy to Operate**
Flip a switch and the built-in automatic station does the work for you, electrically (no air supply required) ...lets you make up to 120 tests per hour...safety interlocks eliminate operator error, permits use of non-technical personnel.
- **Guaranteed Accurate and Safe**
Constant 10^{-10} cc/sec accuracy guaranteed by the patented VEECO VEETUBE®...it cleans itself...uses safe, inert helium as tracer gas.
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Each MS-9 undergoes a full week (168 hrs) of test run and inspection before shipment.

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PACKAGED
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LEAK DETECTORS

Finds leaks in hermetically sealed components

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FREE MS-9 BROCHURE contains full details on performance, specifications, operation and advantages. There is an MS-9 series Leak Detector to fill your exact need. Write Department A-1435.

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VEECO VACUUM CORP.
86-B Denton Avenue, New Hyde Park
Long Island, New York
HIGH VACUUM & LEAK DETECTION EQUIPMENT

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A SET OF PRACTICAL DESIGN DATA FOR QUARTERWAVE COAXIAL (TEM) CAVITIES

GLYN BOSTICK
PRESIDENT and CHIEF ENGINEER
Radar Design Corporation • Syracuse, New York

By use of the information given below, dimensional design can be carried out for coaxial resonant cavities.

The data is simplified for rapid use and theoretical relationships have been altered to conform with observed results. Some experimental adjustment will usually be required to refine coupling dimensions.

The assumption has been made that the cavity is working out of and into a 50 ohm system — the usual case — and that the cavity characteristic impedance is 70 ohms (optimum Q).

The data can be used in any of several ways as illustrated below:

1. *Verification of Specifications.*

Specifications drawn in advance of actual construction many times contain sets of conditions that are physically incompatible.

In the case of coaxial cavities, the following parameters are generally specified:

Maximum diameter (D) (for space considerations).
Maximum Insertion Loss.
Operating Bandwidth.

The verifying procedure would be as follows:

a. From chart 1, the unloaded Q (Q_u) can be obtained since D and frequency are known.
b. The insertion loss can be obtained from chart 2 since Q_u has been obtained from chart 1 and Q_L is known from the operating bandwidth specified.
c. The insertion loss so obtained can be compared with that specified to see if this is an impractical specification.

2: *Design of the Cavity from a given Set of Operating Specifications.*

Assuming that operating frequency, bandwidth and maximum insertion loss are specified:

a. Unloaded Q (Q_u) is obtained from chart 2.
b. From chart 1, the minimum diameter (D) required can be obtained.
c. From the equation in illustration 3, one can solve for the ratio $\frac{r}{A}$.

GLYN BOSTICK was born in 1923 at Fort Worth, Texas. He graduated from Yale University in 1947 with a BE degree. Mr. Bostick worked for Airborne Instruments Laboratory, Inc., Arma Corporation, and Grumman Aircraft Engineering Corporation in the development of antenna and r-f components.

After three years of independent consulting, he founded Radar Design Corporation in 1956, where today he is President and Chief Engineer.

chart 1

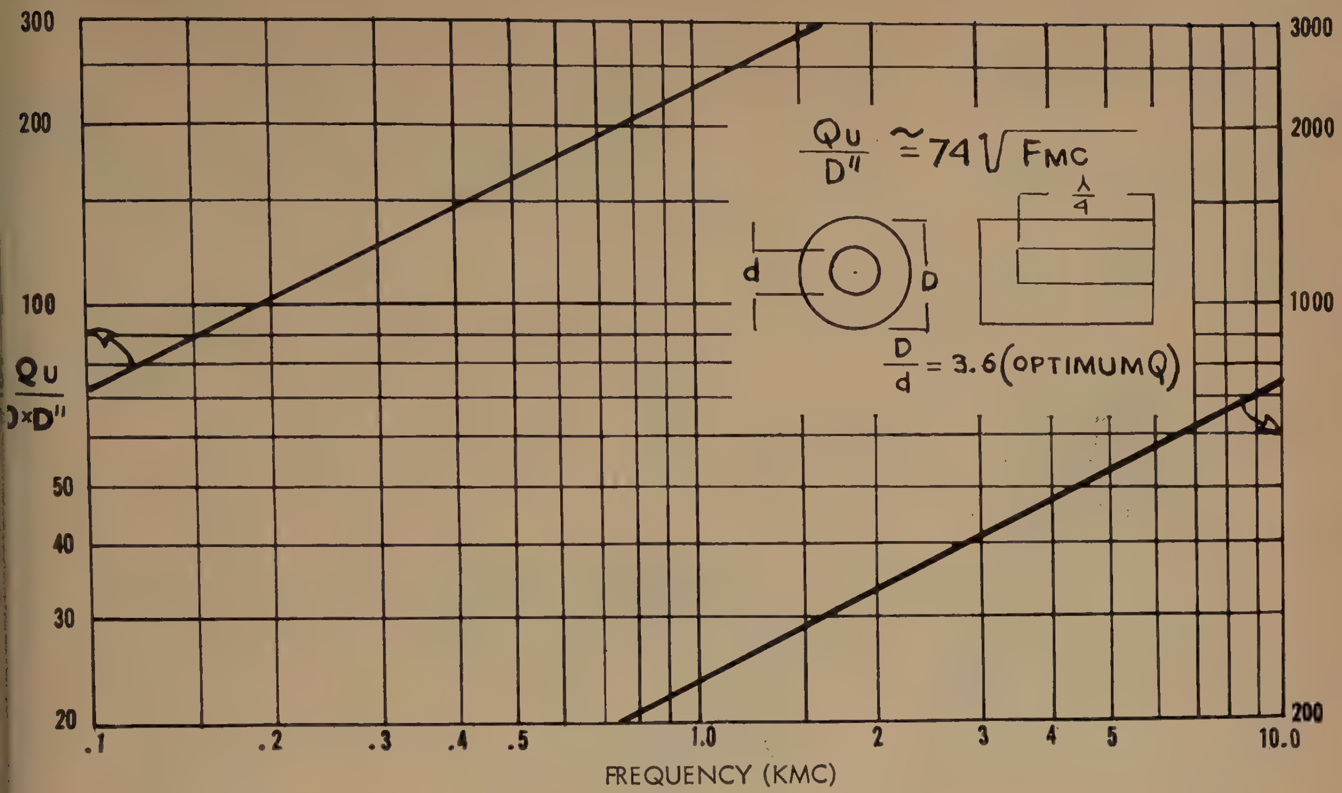
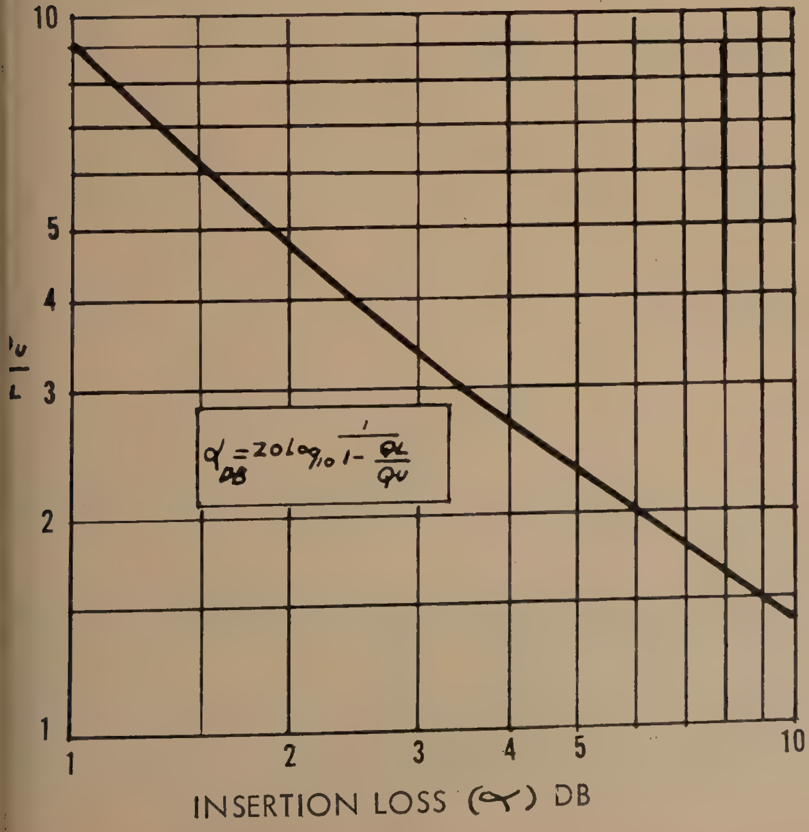
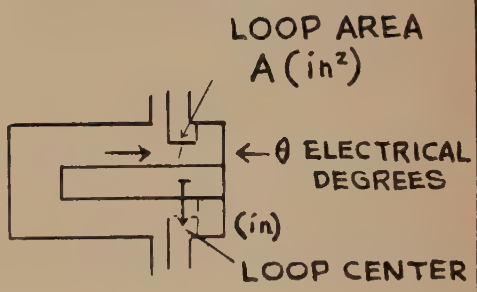


chart 2

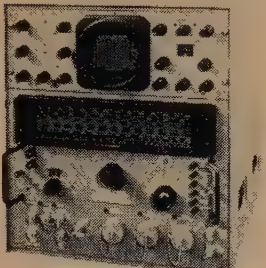




$$Q_L = \frac{4}{3}\left[\left(\frac{r}{A}\right)\frac{1}{(F_{KMC}\cos\theta)}\right]^2$$

ILLUSTRATION 3

extreme sensitivity 10 mc to 44,000 mc



PANORAMIC'S SPA-4 SPECTRUM ANALYZER

MORE USEABLE SENSITIVITY

BAND	RF SENSITIVITY*
10 — 420 MC	—95 to —105 dbm
350 — 1000 MC	—90 to —100 dbm
910 — 2200 MC	—90 to —100 dbm
1980 — 4500 MC	—80 to — 95 dbm
4.5 — 10.88 KMC	—80 to — 95 dbm
10.88 — 18.0 KMC	—70 to — 90 dbm
18.0 — 26.4 KMC	—60 to — 85 dbm
26.4 — 44.0 KMC	—55 to — 85 dbm

*measured when signal and noise equal 2X noise

Using one tuning head which contains one triode and two Klystron oscillators, Model SPA-4 offers more exclusive advantages for applications demanding extreme sensitivity, stability, versatility, accuracy.

- **Three precisely calibrated amplitude scales—40 db log, 20 db linear, 10 db power.**
- **Two independent frequency dispersion ranges—continuously adjustable—0-70 mc and 0-5 mc. Negligible internal frequency modulation permits narrow band analysis of FM problems.**
- **Variable I.F. bandwidth from 1 kc to 80 kc.**
- **Push-button frequency selector.**
- **Synchroscope output with 40 db gain.**
- **Accurate measurement of small frequency differences. A self-contained marker oscillator, modulated by a calibrated external generator, provides accurate differential marker pips as close as 10 kc.**

Tremendous flexibility and many unique advances of Panoramic's compact SPA-4 make it unsurpassed for visually analyzing FM, AM and pulsed signal systems; instabilities of oscillators; noise spectra; detection of parasitics; studies of harmonic outputs; radar systems and other signal sources.

Write, wire or phone today for detailed SPA-4 bulletin.

the pioneer is the leader

eem

Panoramic
RADIO PRODUCTS INC.

556 So. Fulton Ave., Mount Vernon, N.Y.
OWens 9-4600
Cable: Panoramic, Mt. Vernon. N.Y. State

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Industry News

(Continued from page 76)

Prior to joining Gabriel in 1959, Mr. Hamre was sales manager for the General Communications Company.

Mr. Hamre is a graduate of Middlebury College, and attended Boston University College of Business Administration. He is a member of IRE, ISA, and National Sales Executives.

— *mwj* —

NEW SALES ENGINEER FOR ALFRED ELECTRONICS

Robert J. Bach has been named sales application engineer for Alfred Electronics, Palo Alto, California manufacturer of precision microwave instruments.

Bach comes to Alfred from Hewlett-Packard Company, where he had been an instrument sales engineer in that firm's marketing department since 1958.

Prior to 1958, Bach was a member of the Army Rocket and Guided Missile team, Redstone Arsenal, and was assigned as resident ordnance engineer for the Nike missile guidance package at Western Electric in Winston-Salem, N.C.

Bach's experience also includes four years as project engineer with the Navy Department, Bureau of Ships, in the Electronics Division of the Air Navigational Aids Section. He received his BSEE degree from Marquette University in 1951.

— *mwj* —

LITTON ANNOUNCES TWO APPOINTMENTS

Litton Industries recently announce the appointmnets of Stuart G. Whittelsey as Assistant General Manager of the Electron Tube Division and Donald T. Fowler as Advertising Manager of the four-division components group.

Litton divisions for which Mr. Fowler will handle advertising and sales promotion are Airtron, Triad Transformer, U.S. Engineering Co., and the Potentiometer Division.

Mr. Fowler came to his new post from the headquarters advertising and publi relations office of Litton Industries in Beverly Hills, Calif.

Previously he had directed advertising, sales promotion and public relations for TelAutograph Corp., Los Angeles, and the Baroid Division of National Lead Company in Houston, Texas.

Mr. Whittelsey will be responsible for market research, according to the announcement made by Dr. Norman H. Moore, Vice-President of Litton Industries and Electron Tube Division General Manager.

Since 1958, Mr. Whittelsey has been Manager of the Litton Industries Dayton (Ohio) office. He was previously in charge of Customer Relations for the Electron Tube Division.

Mr. Whittelsey served as an officer in the United States Air Force, Headquarters, Air Material Command, Wright Patterson Air Force Base, Ohio. He is a graduate of Stanford University and Harvard Business School.

— *mwj* —

LITERATURE . . .

CASWELL CATALOG

A new short form catalog has been announced by Caswell Electronics Corporation, 414 Queens Lane, San Jose, California. It features several new coaxial components and a complete new series of temperature compensated ferrite isolators in waveguide and coax.

Other new items include a coaxial dc block, an adjustable isolator, a coaxial variable attenuator and a double stub tuner with the stubs off center so that line length can be changed by reversing the unit. Many of these items have not previously been available to the industry from catalog stock.

Prices and delivery schedules are listed.

Circle Reader Service Card 114

— *mwj* —

LEL CATALOG

A new brochure has been issued by LEL, Inc., manufacturers of ultra-sensitive receiving systems and equipments in the fields of communications (terrestrial and space), telemetry, guidance and control and navigation. The brochure describes the capabilities and facilities of LEL, the range of products developed, and includes a partial listing of the customers who utilize them. The experience of key personnel as well as the background of the company is outlined.

A copy of this brochure will be sent to readers who request it.

Circle Reader Service Card 115

— *mwj* —

NOW

A COMPLETE LINE OF ELECTRONICALLY SWEPT MICROWAVE SIGNAL SOURCES FROM

wave particle

MODEL 630-X

MODEL 630-X
8.2 - 12.4 KMC

Power Output	20 mw. (minimum)
Sweep Rate	C.W. or 0.1 – 100 CPS
Sweep Width	A Few MC. to 4.2 KMC
A.M. Modulation	800 – 1200 CPS Square Wave
Sweep Output	Linear Sawtooth
Oscillator	Varian VA-161
Price	$2,850.00
Delivery	2 – 4 Weeks

OTHER MODELS:

MODEL	FREQUENCY (KMC)
630-L	0.98 - 2.1
630-S	2.0 - 4.0
620-C	4.0 - 8.0
630-CX	4.8 - 9.6
630-X	8.2 - 12.4
610-XKU	8.0 - 16.0
630-KU	12.4 - 18.0
620-K	18.0 - 27.0
621-K	15.5 - 24.0
600-KA	26.5 - 41.0
600-V	63.0 - 75.0

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PGMTT NATIONAL SYMPOSIUM for 1960

SAN DIEGO, CALIFORNIA . . . MAY 9-11

San Diego's Hotel del Coronado will be the scene of the 1960 PGMTT National Symposium, May 9, 10 and 11.

The Symposium will open Monday morning, May 9, with a welcome by David Proctor, Convair-Astronautics, the Symposium Chairman, and opening remarks will be given by Dr. Arthur Oliner, Polytechnic Institute of Brooklyn, National Chairman of the PGMTT.

The customary banquet will be held in the Crown Room of the Hotel del Coronado on Tuesday evening, May 10. Dr. W. A. Edson, Manager, Klystron Subsection, General Electric Company, will be the banquet speaker. His subject will be "Future Microwave Power Sources," and will deal with trends in microwave power tubes. He will rely on the known history of devices and applications, together with foreseeable trends such as space travel and world-wide communications, to provide a reasonable basis for projecting future activities.

The technical program will include papers and panel discussions on the general subjects of Microwave Components and Systems, Parametric Amplifiers, Ferrites, Millimeter Waves and Diode Applications, Microwave Propagation in Plasmas and Solids, and Filters and Measurements.

Program of technical sessions follows:

1960 PGMTT National Symposium Committee. Left to right: W. E. Moore, Convair, Recorder; H. B. Babbitz, Convair, Publicity; Mrs. K. Abbey, Women's Activities; B. I. Small, Naval Electronics Laboratory, Financial; D. Proctor, Convair-Astronautics, Chairman; R. C. Hansen, Space Technology Labs, Administrative Committee Representative; D. B. Medved, Convair, Technica Program; H. D. Dickstein, Cubic Corporation, Local Arrangements. Not present were R. E. Honer, Convair, Section Representative, and C. E. Moe, San Diego State College, San Diego State Representative.

TECHNICAL PROGRAM

Monday Morning, May 9

SESSION 1

Microwave Components and Systems

Chairman: T. N. Anderson

FXR, Inc., Long Island City, N.Y.

"New Developments in Microwave Communication Systems," *C. C. Cutler,* Bell Telephone Labs., Holmdel, N.J.

"Mode Conversion in Helix Waveguide," *H. G. Unger,* Bell Telephone Labs., Holmdel, N.J.

"Some Properties of Dielectric Loaded Slow Wave Structures," *G. B. Walker* and *C. G. Englefield,* Univ. of British Columbia, Vancouver, B.C., Canada.

"UHF Strip Transmission Line Hybrid Junction," *I. Tatsughuchi,* Bell Telephone Labs., Whippany, N.J.

"A Variable Slope, Non-Dispersive Microwave Phase Shifter," *G. D. Carey* and *R. E. Hovda,* Autonetics, Div. of North American Aviation, Downey, Calif.

"A Wide-Band Turnstile Junction and Direction Finding Antenna," *R. C. Honey* and *J. K. Shimizu,* Stanford Res. Inst., Menlo Park, Calif.

"Microwave Phase Analyzer," *K. D. Claborn* and *R. E. Jones,* Bendix Radio, Div. of Bendix Aviation Corp., Baltimore, Md.

Monday Afternoon, May 9

SESSION 2

Parametric Amplifiers

Chairman: A. Berk

Research Labs., Hughes Aircraft Co.
Culver City, Calif.

Gallium Arsenic Point Contact Diodes," *W. M. Sharpless,* Bell Telephone Labs., Holmdel, N.J.

Characterization of Microwave Variable Capacitance Diodes," *S. T. Eng,* Development Lab., Hughes Semiconductor Div., Newport Beach, Calif.

A Perturbation Theory for Parametric Amplifiers," *R. H. Kingston* and *A. McWhorter,* Lincoln Lab., MIT, Lexington, Mass.

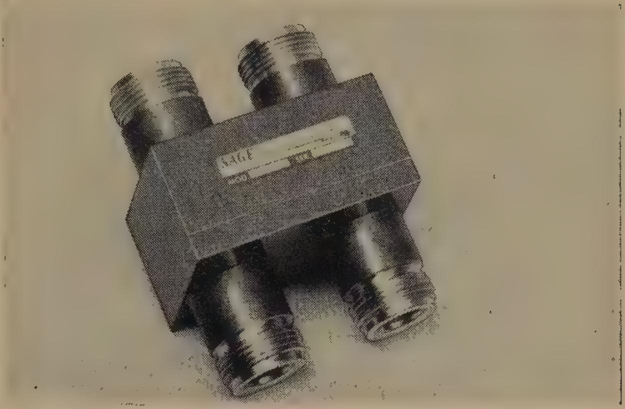
A Study of the Optimum Design of Wideband Parametric Amplifiers and Up-Converters," *G. L. Matthaei,* Stanford Res. Inst., Menlo Park, Calif.

A Low-Noise X-Band Parametric Amplifier," *R. D. Weglein,* Research Labs., Hughes Aircraft Co., Culver City, Calif., and *F. Keywell,* Semiconductor Div., Hughes Products, Costa Mesa, Calif.

A Four Terminal Low Noise Parametric Microwave Amplifier," *W. Eckardt* and *F. Sterzer,* RCA, Princeton, N.J.

Design and Operation of Four-Frequency Parametric Up-Converters," *J. Luksch, E. W. Matthews,* and *G. Verwys,* RCA, Moorestown, N.J.

A Study of the Herated Traveling Wave Parametric Amplifiers," *C. V. ell,* Walla Walla College, College Park, Wash.



SAGE

Shown above is the Sage Model 753 miniaturized stripline hybrid. All units have a coupling of 3 ± .5 db and directivity in excess of 20 db over the specified frequency range. The Sage stripline hybrids are normally furnished with Type "N" connectors.

Delivery on some types is from stock, others are within 30 days after receipt of an order.

Model No.	*Frequency Range*	*(Dimensions Excluding Connectors)* *Width*	*Height*	*Length*	*Price*
749	125- 250 mc	7/8"	1 3/8"	11 3/4"	$175.00
750	250- 500 mc	7/8"	1 3/8"	5 3/4"	$175.00
751	500-1000 mc	7/8"	1 3/8"	3 1/2"	$175.00
752	1000-2000 mc	7/8"	1 3/8"	2 1/8"	$175.00
753	2000-4000 mc	7/8"	1 3/8"	1 5/8"	$175.00

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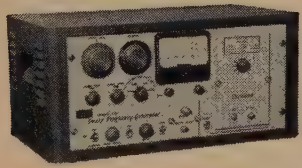
R. F. Test Equipment

Quantitative Measurements Using Sweep Frequency Techniques

Model 900A—THE MOST VERSATILE SWEEP GENERATOR $1,260^{00}

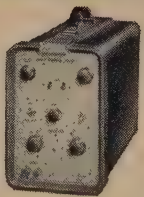
CENTER FREQUENCY—VHF 0.5 to 400 MC UHF 275 to 1000 MCS—SWEEP WIDTH—up to 400 MCS—FLATNESS—±0.5 db over widest sweep!



Model 707—ULTRA FLAT SWEEP GENERATOR $795^{00}

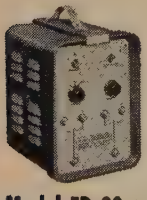
Featuring ±5/100 db flatness—Plug-in osc. heads*; variable sweep rates from 1/min. to 60/sec.; all electronic sweep fundamental frequencies; sweep width min. of 1% to 120% of C.F.

*Heads available within the spectrum 2 to 265 MCS



Models 601/602—PORTABLE GENERAL PURPOSE $295.00

COVERAGE—Model 601—12 to 220 MCS. Model 602—4 to 112 MCS—FLATNESS — ±0.5 db OUTPUT—up to 2.5 V RMS WIDTH-1% to 120% of C.F.



Model FD-30 $250.00

High speed DPDT coaxial switch permitting oscilloscope measurements without calibration—all measurements referenced continuously against standard attenuators.

Model AV-50
Variable Precision Attenuator $150.00

Long life rotary switches; dual wiping silver contacts on "Kel-F" dielectric. 0-62.5 db in ½ db steps; DC to 500 MCS.

Write for catalog and technical Newsletter series on measurements using sweep frequency techniques. Prices and data subject to change without notice.

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PGMTT Symposium

(*Continued from page 83*)

Monday Evening, May 9

SESSION 2A

Parametric Amplifiers

Panel Discussion:

- *A. Berk,* Hughes Aircraft Co., Research Labs., Culver City, Calif.
- *C. J. Carter,* Space Technology Labs., Los Angeles, Calif.
- *J. C. Green,* Airborne Instruments Lab., Melville, L.I., N.Y.
- *E. M. T. Jones,* Stanford Res. Inst., Menlo Park, Calif.
- *N. Uenohara,* Bell Telephone Labs., Murray Hill, N.J.
- *G. Wade,* Stanford Univ., Stanford, Calif.

Tuesday Morning, May 10

SESSION 3

Ferrites

Chairman: N. Sakiotis
Motorola, Inc., Scottsdale, Arizona

1. "Non-Linear Effects in Ferrites," *M. Weiss,* Research Labs., Hughes Aircraft Co., Culver City, Calif.
2. "Ferroxplane Type Materials at Microwave Frequencies," *I. Bady,* U.S. Army Signal Res. & Dev. Lab., Fort Monmouth, N.J.
3. "Antiferromagnetic Materials for Millimeter and Sub-millimeter Devices," *G. S. Heller* and *J. J. Stickler,* Lincoln Lab., MIT, Lexington, Mass.
4. "Design Problems Associated with Rectangular Waveguide Reciprocal Phase-shifters," *A. Clavin,* RANTEC Corp., Calabasas, Calif.
5. "Magnetstatic Modes and Ferrites with Conventional Waveguide Geometrics," *G. P. Rodrigues,* Sperry Microwave Electronics Co., Clearwater, Fla.
6. "Wide Band Resonance Isolator," *W. W. Anderson* and *M. E. Hines,* Bell Telephone Labs., Murray Hill, N.J.
7. "An Electrically-Variable, Reciprocal Ferrite Phase Shifter," *R. W. Kordos* and *V. J. McHenry,* Research Lab., Div., Bendix Aviation Corp., Detroit, Mich.

Tuesday Afternoon, May 10

SESSION 4

Millimeter Waves and Diode Applications

Chairman: P. Vartanian
Melabs, Palo Alto, Calif.

1. "Millimeter Wave Generation," *B. Epsztein,* Microwave Res. Inst., Brooklyn, N.Y. (on leave from Compagnie General TSF, France).
2. "Millimeter Wave Generation by Parametric Methods," *G. H. Heilmeier,* RCA Labs., David Sarnoff Res. Center, Princeton, N.J.
3. "A Pulsed Ferrimagnetic Microwave Generator," *B. J. Elliott, T. Schaug-Pettersen* and *H. J. Shaw,* Stanford Univ., Stanford, Calif.
4. "Maser Operation at Signal Frequencies Higher Than the Pump Frequency," *F. R. Ames,* Airborne Instruments Lab., Melville, L.I., N.Y.
5. "Generation of Microwaves by Means of Esaki Diodes," *R. F. Rutz,* Research Labs., IBM, Poughkeepsie, N.Y.
6. "The Large Signal Behavior of a Cavity Type Parametric Amplifier," *F. A Olson* and *G. Wade,* Stanford Univ., Stanford, Calif.
7. "A Solid State Microwave Source from Reactance Diode Harmonic Generators," *T. M. Hyltin* and *K. L. Kotzebue,* Texas Instruments, Dallas, Texas

Wednesday Morning, May 11

SESSION 5

Microwave Propagation in Plasmas and Solids

Chairman: L. Goldstein
Univ. of Illinois, Urbana

1. "Propagation of Waves in a Plasma in a Magnetic Field," *W. Allis,* Research Lab. of Electronics, MIT, Cambridge, Mass.
2. "Plasma - Electromagnetic Interaction," *N. Marcuvitz,* Microwave Res. Inst. Polytechnic Institute of Brooklyn Brooklyn, N.Y.
3. "Magnetoplasma Effects in Semiconductors," *B. Lax,* Lincoln Labs., MIT Lexington, Mass.
4. "Coherent Excitation of Plasma Oscillations in Solids," *D. Pines,* Univ. o Illinois, Urbana (work done at Genera Dynamics Corp., San Diego, Calif.).

Panel Discussion:

- *O. T. Fundingsland,* Raytheon Mfg. Co. Waltham, Mass.
- *R. Gould,* California Institute of Technology, Pasadena.
- *H. Margenau,* Yale University, New Haven, Conn.
- *R. F. Whitmer,* Sylvania Electronic System, Mountain View, Calif.

Wednesday Afternoon, May 11

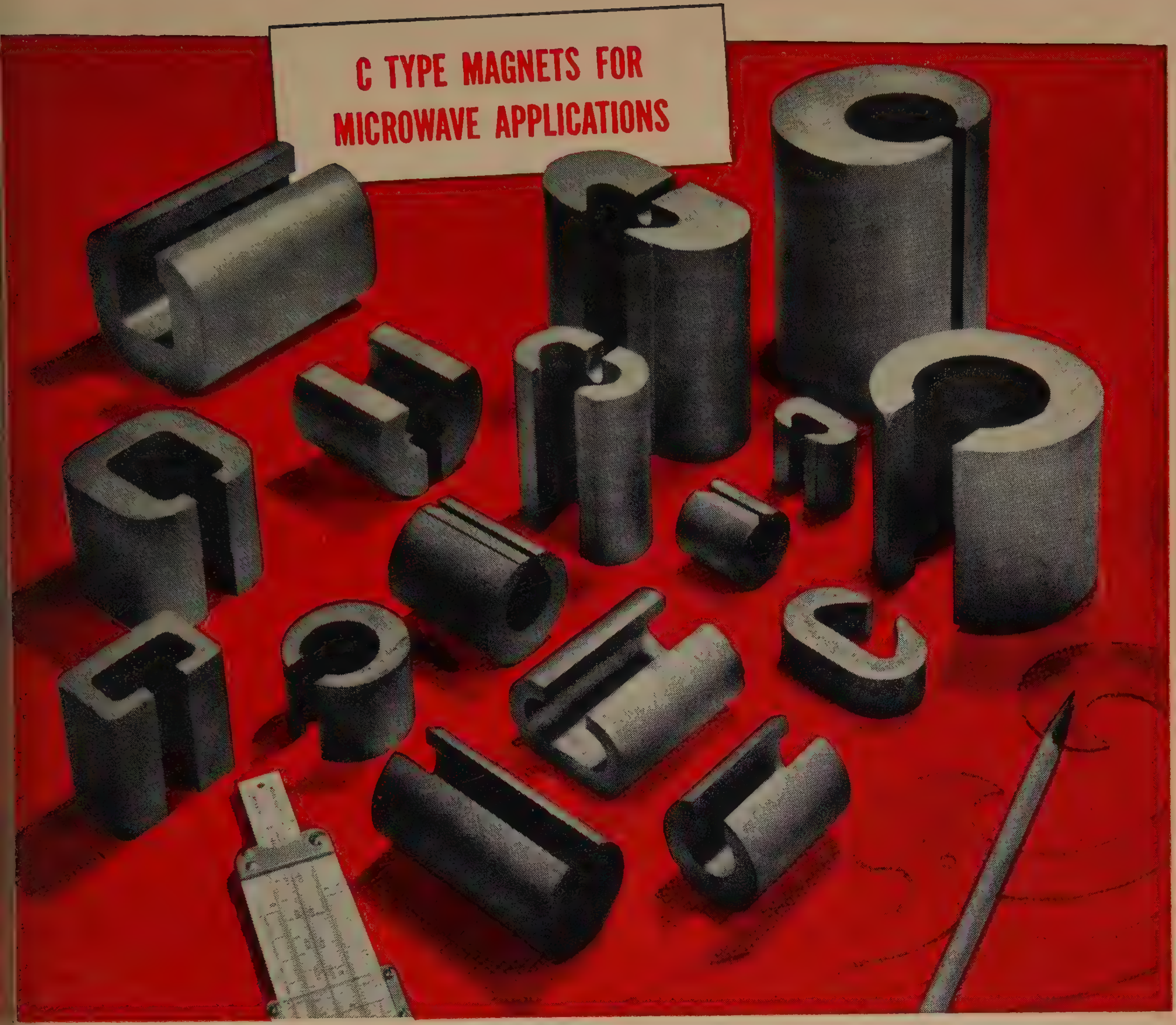
SESSION 6

Filters and Measurements

Chairman: K. Tomiyasu
General Electric Microwave Lab.
Palo Alto, Calif.

1. "Lossy Waveguide Resonators," *H Riblet,* Microwave Development Labs Inc., Wellesley, Mass.
2. "Peak Internal Fields in Direct Couple Cavity Filters," *L. Young,* Westinghouse Electric Corp., Baltimore, Md.
3. "Strip Transmission Line Directiona Filter," *R. L. Sleven* and *P. E. Dorat* Airborne Instruments Lab., Melvill L.I., N.Y.
4. "Application of the Smith Chart t Problems of Propagation in a Magneto Ionic Medium," *G. A. Deschamps* an *W. L. Weeks,* Univ. of Illinois, Urban
5. "Microwave Measurements of Electro Attachment Rates," *V. A. J. van Li* and *E. G. Wilkner,* General Atomi Div. of General Dynamics Corp., Sa Diego, Calif.
6. "Fractional Millimicrosecond Electric Stroboscope," *W. M. Goodall* and *F. Dietrich,* Bell Telephone Labs Holmdel, N.J.

— *mwj* —



C TYPE MAGNETS in a wide range of sizes to meet your design needs in

★ Transverse Field Isolators ★ Differential Phase Shifters ★ Duplexers

Arnold C-type Alnico Magnets are available in a wide ection of gap densities ranging from 1,000 to over 7,500 asses. There are six different basic configurations with a le range of stock sizes in each group.

The over-all size and gap density requirements of many totype designs can be met with stock sizes of Arnold C gnets, or readily supplied in production quantities.

When used in transverse field isolators, Arnold C Mag s supply the magnetizing field to bias the ferrite into the ion of resonance, thus preventing interaction between crowave networks and isolating the receiver from the nsmitter. These magnets are also used in differential se shifters and duplexers, and Arnold is prepared to ign and supply tubular magnets to provide axial fields circular wave guides.

A feature of all Arnold C Magnets is the excellent field uniformity along the length of the magnet. Versatility in design may be realized by using multiple lengths of the same size magnet stacked to accomplish the needs of your magnetic structure.

Let us work with you on any requirement for permanent magnets, tape cores or powder cores. ● For information on Arnold C Magnets, write for Bulletin PM-115. Address *The Arnold Engineering Company, Marengo, Illinois.*

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Microwave Cavities

TRIODE OSCILLATORS

C Band

S Band

Whether you require the use of S band or C band triode transmitter and receiver oscillators, or tunable filters, John Gombos Co., Inc. provides complete design, manufacture and test of these and all other types of microwave assemblies, including sub-systems.

John Gombos Co., Inc.
Webro Road, Clifton, New Jersey

MICROWAVE MECHANICAL
GOMBOS
ELECTRO-MECHANICAL ELECTRONIC SYSTEMS

Write For FREE
Descriptive Literature
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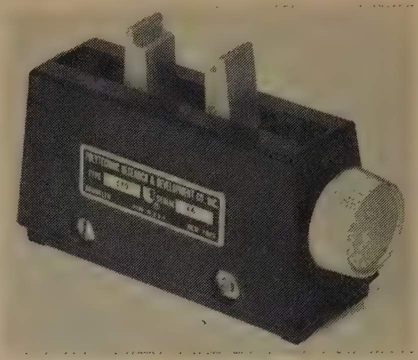
NEW PRODUCTS

UNIVERSAL WAVEGUIDE STAND



Latest addition to the line of Microwave Equipment of the Polytechnic Research & Development Co., Inc., Brooklyn, New York, is the PRD 370 Universal Waveguide Stand.

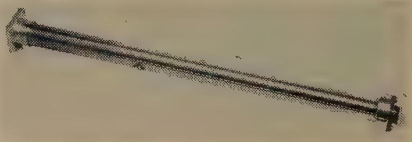
This new universal stand accommodates all waveguide sizes used in the frequency range of 2.60 to 40.0 kmc/s.

The PRD 370 features a continuously adjustable set of jaws which firmly grips the sidewalls of the waveguide and simultaneously locates the transmission line center plane three inches above bench level.

Circle Reader Service Card 133

— *mwj* —

GAS TUBE NOISE SOURCES FOR THE 200-250 MC RANGE



Supplementing the recently announced development and production of compact gas tube noise sources for ground and airborne microwave system applications, Tucor, Inc., of South Norfolk, Conn. has announced the availability of additional coaxial models for the 200-250 mc frequency range. Available as the T44V series, these new noise sources feature exceptionally high excess noise outputs. They are ideal for test and calibration of all types of microwave and communications components and systems.

The T44V1C is one of several models now available. This noise source is housed in sturdy coaxial line and provides an excess noise ratio of 18.5 ± 0.3 db. The T44V1C is suitable for cw or pulse operation under typical adverse military environments, and will meet all applicable military specifications for shock, vibration, temperature and humidity. The T44V1C will fire and operate at conventional power supply voltages and will operate reliably for a lifetime in excess of 2,000 hours.

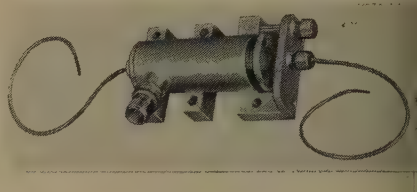
Two additional models, the T44V2C and the T44V3C, are also available. The T44V2C features a replaceable gas tube element as well as a higher noise output of 21.0 db. The T44V3C also features the replaceable gas tube element, at a noise output of 18.5 db.

For special applications as to frequency or noise output, Tucor can provide a noise source tailored to your requirements. Coaxial versions of the T44V series are available at frequencies up to 1000 mc.

Circle Reader Service Card 134

— *mwj* —

JOHN GOMBOS INTRODUCES COMPLETE LINE OF MICROWAVE COMPONENTS



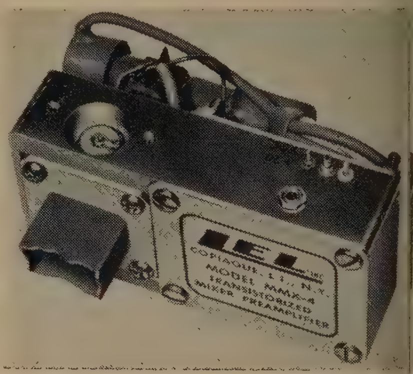
In a recent statement made by company president, John Gombos, it was announced that John Gombos Company, Inc. is introducing its first product line of microwave components.

One of the products in the line is a complete microwave subsystem for use in "C" band. This consists of a "C" band triode local oscillator (as shown in the photo), two-cavity preselector, T-junction diplexer and coaxial mixer. The preselector, diplexer, mixer package is contained in 3½ cubic inches and weigh only 9 ounces. The "C" band oscillator which tunes from 5400-5900 megacycles measures 4 inches long, 1½ inches wide and 1 inch high, and weighs approximately 9 ounces. This subsystem is applicable to superhetrodyne systems with coaxial input, where small size and light weight are of great importance, such as airborne applications.

Circle Reader Service Card 135

— *mwj* —

LEL ANNOUNCES TWO NEW MIXER-PREAMPLIFIER ASSEMBLIES



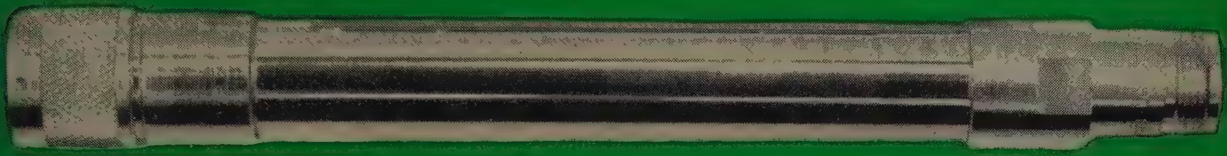
LEL, Inc., of Copiague, New York has introduced two new models in its series of matched microwave-mixer-preamplifier assemblies.

The MMX-4 is a transistorized assembly for the range 8.5 to 9.6 kmc. It has a 15 mc bandwidth centered at 60 mc output frequency, 20 db minimum overall gain, and an overall noise figure of 10 db. The MMX-4, used in conjunction with LEL Series 80 or 82 transistorized I.F.

NEW! MINIATURE LIGHTWEIGHT ISOLATORS

FOR RADAR AND COMMUNICATIONS SYSTEMS

ACTUAL SIZES



MODEL D44L7

MODEL D44S7

MODEL D44C7

TYPICAL SPECIFICATIONS

Model	D44L7	D44S7	D44C7
Frequency Range (kmc)	1.25 - 1.35	2.70 - 3.10	5.40 - 5.90
Peak Power	5 kw	5 kw	5 kw
Average Power	5 w	5 w	5 w
Max. Insertion Loss	0.9 db	0.9 db	0.9 db
Minimum Isolation	15.0 db	15.0 db	15.0 db
*Maximum VSWR	1.20	1.20	1.15
Connectors			
Input	N male	N male	N male
Output	N female	N female	N female
Diameter	0.78 in	0.78 in	0.78 in
Length	6.61 in	4.47 in	4.25 in
Weight	6 oz	5 oz	4 oz
Price	$235.00	$225.00	$225.00

*Assume 2:1 Max. Load VSWR

Difficult packaging problems? Here is Sperry's unique approach in miniaturized ferrite isolators. This design provides improved performance *without* bulky, external magnets.

The result: a lightweight, well shielded, compact, and rugged isolator suitable for applications previously not considered feasible. Units similar to the above are also available in communications and UHF bands.

SPERRY

PERRY MICROWAVE ELECTRONICS COMPANY, *CLEARWATER, FLORIDA · DIVISION OF SPERRY RAND CORPORATION*

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MICROWAVE ENGINEERS

Continued expansion has created exceptional opportunities for Senior Engineers in field of:

Waveguide Components
System Assemblies
and
Microwave Test Equipment Design

Top salaries, unexcelled working conditions and engineering challenge provide an unusual opportunity for aggressive qualified engineers seeking a promising future.

- *All Benefits*
- *Top Salaries*
- *New Air Conditioned Plant*
- *Fast Growing Organization*

WAVELINE Inc.
at Caldwell-Wright Airport
Caldwell · New Jersey
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New Products

(*Continued from page 86*)

amplifiers, permits production of all solid-state microwave receivers.

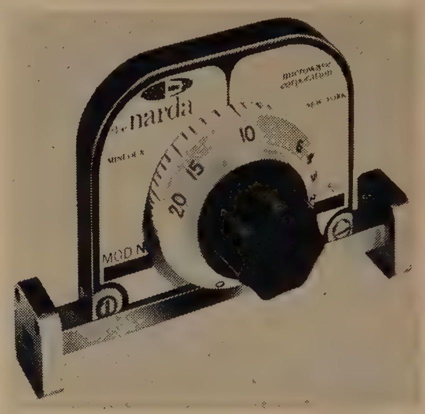
The MMX-5 covers the range of 8.5 to 9.6 kmc and provides an I.F. output bandwidth of 100 mc. It has an I.F. center frequency of 250 mc, a gain of 15 db, and an overall noise figure of 10 db.

Circle Reader Service Card 136

— *mwj* —

NARDA INTRODUCES DIRECT-READING SEMI-PRECISION VARIABLE ATTENUATORS

A line of low-cost, direct-reading Variable Attenuators offering precision and accuracy nearly comparable to expensive *precision* attenuators has been introduced by The Narda Microwave Corporation, Mineola, L.I., N.Y.



A unique, though simple, new design principle utilizing a variably inserted Narda-Iron cam provides minimum frequency sensitivity and low VSWR over the entire frequency and attenuation range The direct reading dial is accurately calibrated to within 1 db up to 10 db and 1.5 db up to 20 db over the entire waveguide frequency range. Maximum attenuation exceeds 25 db and minimum insertion loss is under 0.5 db.

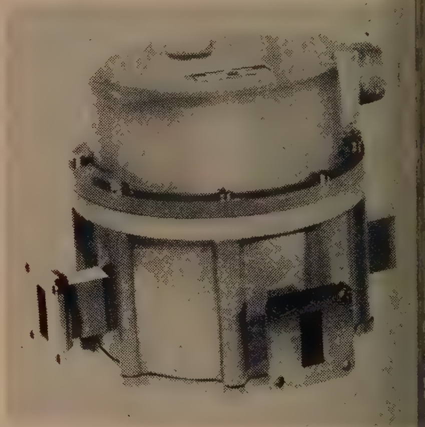
A multi-turn knob drive permits smooth mechanical movement which is free from back lash. All models are extremely well shielded. Standard cover flanges are included on all units. Extremely useful in the millimeter wave region, attenuators of this type are particularly recommended for relatively precise power level setting impedance matching, and isolation (padding).

Models are available for K and V bands at $150 and $180, respectively; for Q M and E bands at $200 each. Model numbers are the same as Narda's original variable attenuators, which the new units supersede. All are available from stock subject to prior sale, through Narda's local representatives.

Circle Reader Service Card 13

— *mwj* —

D-B WAVEGUIDE SWITCHES



New E-plane waveguide switches manufactured by DeMornay-Bonardi, Pasadena California, may be operated by direct or remote control.

Two switch types are available. The first is a 2-way exchange, which switches common waveguide to either adjacent guide. The disconnected waveguide is terminated in a matched load. The second type is a 4-way exchange, which switches two pairs of waveguides.

Each unit consists of a cylindrical housing with waveguide flanges brought out for the positions required. Switching is accomplished by a solenoid-operated rotor.

The switches are designed for high power and provide high channel separation. Remote indication or interlock of other functions can be controlled through two micro-switches which are controlled by switch position. Remote control boxes are available for remote indication and control.

Available in sizes to cover the range 2.6 to 90 kmc, delivery on most units 2 weeks from receipt of order and prices range from $591.00 to $919.00.

Circle Reader Service Card 13

— *mwj* —

MICROWAVE RESEARCH SUPERVISOR

Nationally known research organization has an exceptional opportunity for an Electronic Engineer or Physicist with outstanding technical and administrative competence, to direct its broadly diversified research and development activities in the following areas:

Microwave Components • Propagation Studies
Special Test Equipment • Interference Evaluation
Antenna Development

As Microwave Research Supervisor you will be joining a staff of approximately 100 electronics research and development engineers with a growing reputation. Our environment is midway between academic and industrial research and offers an unusual opportunity to develop research programs of greatest appeal to you and your staff. You will receive a competitive salary plus liberal insurance and retirement benefits in addition to four weeks vacation after one full calendar year of service. Our location in a major midwestern city offers excellent cultural and recreational opportunities.

If you are an exceptionally qualified engineer with an advanced degree and 8 to 10 years of diversified microwave research experience who desires an unusual opportunity for professional advancement, send a complete resume, in confidence, to:

Box A-12
c/o the microwave journal
160 Warren Street
Boston 19, Massachusetts

ANDREW CORPORATION offers a wealth of engineering experience in the field of super power RF transmission devices. A broad line of standard equipment is offered and ANDREW facilities for the development and production of special equipment are without equal.

Available on a production basis is antenna equipment in all of the new, very large waveguide and transmission line sizes, including high power coaxial lines designed with specially shaped inner conductors and insulators to substantially increase voltage ratings.

Typical too, of this equipment are patch panels such as the 9" line model shown above, used for occasional rearrangement of antenna and transmitter connections.

For high speed circuit switching, ANDREW has developed peak reliability, non-contacting waveguide switches such as the 21" model above. Similar switches are also supplied with transitions for use with coaxial line.

Of definite advantage to you is the completeness of the ANDREW line which permits a systems approach with integrated equipment for best performance of the overall system.

Our newly expanded production facilities assure prompt deliveries.

We would welcome your inquiries for product information and engineering assistance on:
Antennas • Feed Horns • Switches • Patch Panels • Duplexers • Power Dividers • Filters • Coaxial Line • Waveguide • Transitions • Adaptors • Bends • Hangers • Dehydrators

WRITE FOR BULLETIN

Circle Reader Service Card 58

Andrew
CORPORATION
363 EAST 75TH STREET • CHICAGO 19
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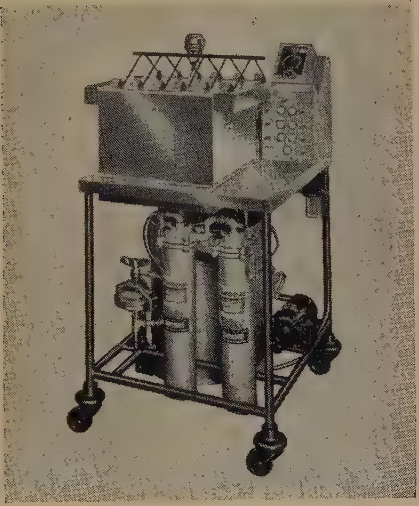
Washington, D.C. • Toronto

BARNSTEAD NEW TRANSISTOR WASHER

FOR WASHING and RINSING TRANSISTORS, DIODES, RECTIFIERS, TUBE PARTS and MATERIALS SUCH AS SILICON AND GERMANIUM



Maintains 15,000,000 OHM ultra-pure water while conserving make-up water through special re-purification cycle.

Best results with faster rinsing and fewer rejects are obtained when ultra-pure, hot water is employed in washing and rinsing of transistors, diodes, and other electronic components. The Barnstead Transistor Washer conserves thousands of gallons of water each day as it repurifies the pure, hot water keeping it free of organic impurities, and submicroscopic particles to 0.45 microns. Completely factory-assembled, ready for operation.

Partial Listing of Firms
Using BARNSTEAD
TRANSISTOR WASHERS

Clevite Transistor, Waltham, Mass.; Motorola, Inc., Phoenix, Arizona; Western Electric Co., Lauderdale, Pa.; Delco, Dayton, Ohio; Minneapolis-Honeywell, Brighton, Mass.; Bell Telephone Laboratories, Somerville, N. J.; Texas Instrument Co., Dallas, Texas and many others.

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48 Lanesville Terrace, Boston 31, Mass.

First in Pure Water Since 1878

New Products

(Continued from page 88)

NEW FLEXIBLE WAVEGUIDE ADAPTER

Douglas Microwave Co., Inc. announces the introduction of their new #105 Waveguide Adapter which presents many significant advantages heretofore unavailable together. This new unit, offered for the first time commercially, is bendable and twistable; stretches and contracts; and boasts an unusually long life. It will prove useful in applications where expansions and/or contractions must be considered, and where continuous bending or twisting is a factor. It is electrically superior to comparable units utilizing flexible waveguides.

The new Douglas Waveguide Adapter covers the 8,000—10,000 mcs frequency range, and will bend 30° and twist 45°. It compresses ⅛″ and expands ⅛″ for each 3″ of length, and is available 3½″, 8″ and 12″ long. Maximum VSWR for all of the above is 1.08 or better throughout the band. The 8″ and 12″ units will permit increased twist and bend while maintaining the same electrical characteristics. Descriptive literature may be obtained without cost or obligation.

Circle Reader Service Card 139

— *mwj* —

LFE ANNOUNCES TWO NEW PRODUCT LINES

Laboratory For Electronics, which recently reported the expansion of its Instrument Division to larger quarters at 714 Beacon Street, Boston, Massachusetts has announced two new product lines.

The first, a complete new line of fixed frequency microwave sources is based on a crystal locked source in which a klystron is locked to a quartz crystal through a unique multiplier chain and IF loop causing the klystron to approach the accuracy of the crystal. The operating frequency and output power are dependent on the klystron used. Units are now available within the frequency range of 2 to 16 kmc with output power up to 1 watt. The series 820 has a long-term stability of 1 part in 10^6 over a 24 hour period and contains incidental FM of only 1 part in 10^8. Applications of this device are found in such endeavors as microwave frequency calibration, parametric amplifier pump sources, radio astronomy, high resolution radar and all other types of research and development where microwave frequencies and all other types of research and de velopment where microwave frequencies ar required with low incidental FM an excellent long-term drift characteristics.

The second, adds three new high powe sources to their current line of ultra-stabl microwave oscillators. The model 814-S-3 covers a frequency range of 3700 to 430 mc and delivers 1 watt. The models 814 C-31 and 814-C-32 are tunable over range of 5900 to 6400 mc and 5400 t 5900 mc respectively and deliver an out put power of 1 and 1.5 watt. All thre units have an incidental FM of less tha 5 parts in 10^8 and long term stabilitie of better than 1 part in 10^6 over a on hour period.

Circle Reader Service Card 14

— *mwj* —

DYMEC HIGH POWER X-BAND SIGNAL GENERATOR

DYMEC, Palo Alto, Calif., a divisio of Hewlett-Packard Co., announces th DY-5381 Signal Generator which delive a minimum power output of 250 milli watts over the range from 8,500 to 10,00 mc, with outputs up to 400 milliwatts i the vicinity of 9,500 mc. The oscillato is tuned through the entire frequency rang by a single knob; the frequency dial approximately calibrated every 100 m The DY-5381 features a continuously-op erating power monitor which permi power setting repeatability within ± 0 db over a wide ambient temperature rang

The instrument includes a 100 db r tary-vane attenuator; output power a curacy is ± 1 db ± 2% of attenuator se ting. Types of modulation provided i ternally are pulse and fm, separately simultaneously, and square-wave. Th pulse length is variable from 0.5 to 2 μsec; the repetition rate is adjustab from 35 to 3500 pps. Internal fm is power line frequency with a maximu deviation of ± 7.5 mc. The intern square-wave frequency is adjustable fro 35 to 3500 cps. Provision is also made f external pulse, fm, and square-wave mo ulation.

Two trigger pulses are provided, o simultaneously with the r-f pulse, the oth advanced from 3 to 150 μsec. Operati of the DY-5381 is unaffected by conne tion to an r-f power source of 1 kw pe or 1 watt average level. The DY-5381 designed for standard rack mounting a is 19″ wide, 14″ high, and 15″ de Delivery is 90 days ARO. Price is $4,8 f.o.b. Palo Alto, California.

Circle Reader Service Card 14

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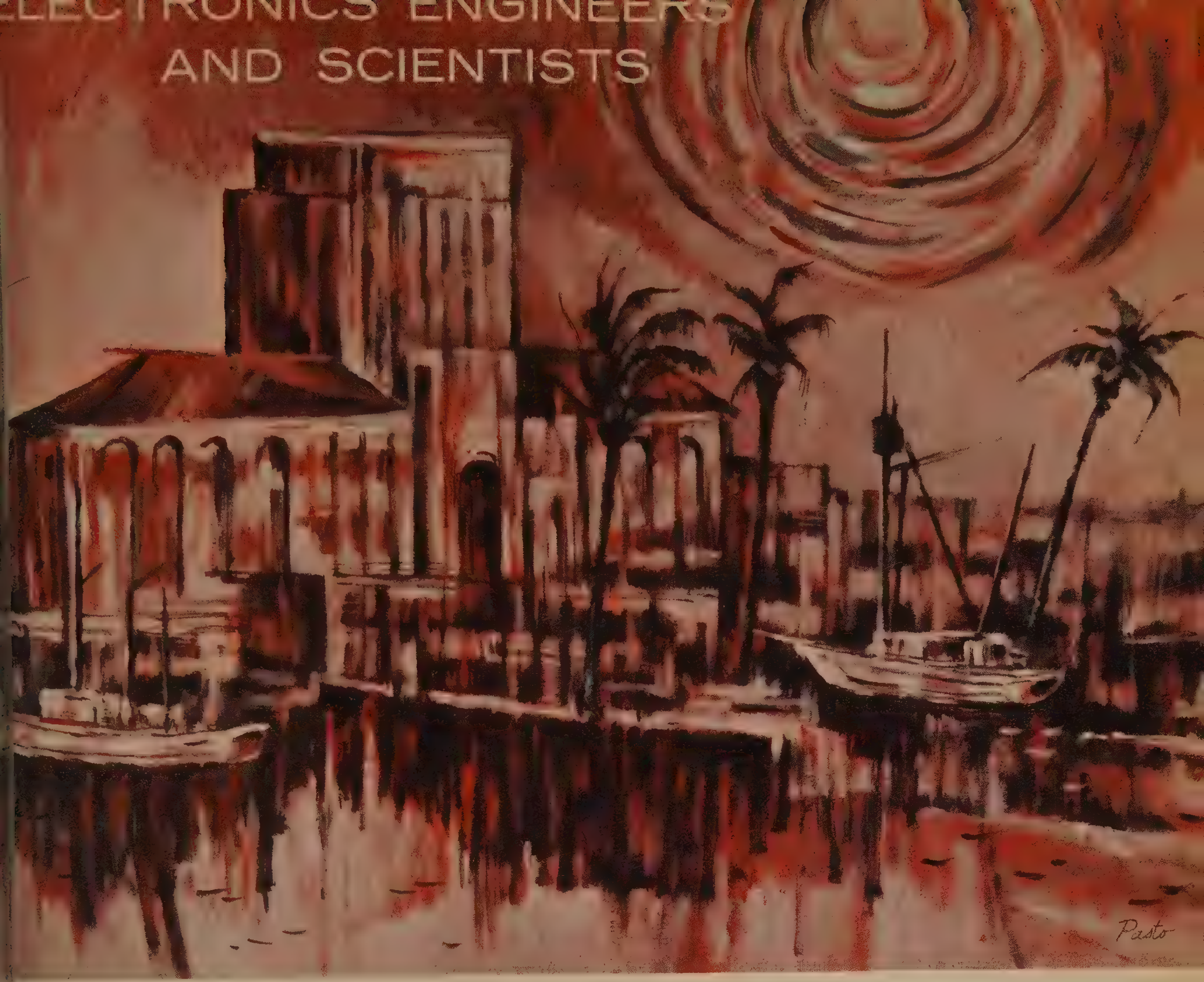
ELECTRONICS ENGINEERS AND SCIENTISTS



San Diego Civic Center, an original painting by Sammy Pasto, Convair/San Diego artist

newly formed
ectronics
rganization at
onvair/San Diego
now being staffed,
ffering truly unusual
pportunities for
gh level electronics
ngineers and scientists.

Electronics engineers and scientists who have demonstrated a level of ability beyond mere competence, will discover the technical challenge they desire at Convair/San Diego Electronics. This newly formed department is now being staffed and affords a truly unusual opportunity to participate in a formulative effort while enjoying the stability of association with a well established company.

Significant research and development is now in progress on infrared and optical systems, advanced radar and communications techniques, space vehicle and missile guidance, submarine detection systems, anti-satellite and AICBM systems, and space weapons systems.

In addition to advanced programs, electronic engineers and scientists at Convair/San Diego Electronics enjoy unsurpassed climate, fine schools and advanced education facilities, and a progressive cultural environment. For further details, please see the next page.

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- Aircraft Antenna Engineers
- Microwave Antenna Engineers
- Microwave Engineers and Physicists
- Radome Engineers
- Electronic Production Engineers
- Electronic Systems Engineers
- Electronic Project Engineers
- Research Engineers (Infrared)
- Ultrasonic Engineers (ASW)

For more complete information, including a copy of a new brochure which explains these activities in more detail, simply complete the form below. This entire page may be removed from the magazine, folded, sealed and mailed in complete confidence.

THE ARTIST — Sammy Pasto, Convair-San Diego artist whose painting appears on the preceding page, is a native of Boston. He studied at the New England School of Art and moved to California following World War II. Presently working as an illustrator at Convair-San Diego, Pasto has received broad recognition for his work in fine arts. He has had one-man shows in New York, Philadelphia and Los Angeles and his work has been accepted in most juried West Coast art shows. For a change of pace, Pasto plays clarinet in a prominent Dixieland jazz band in San Diego.

PROFESSIONAL EMPLOYMENT INQUIRY — This information will enable the professional staff at Convair/San Diego to make a preliminary evaluation of your background. A personal interview can be arranged in your city by appointment. Every completed inquiry will be acknowledged.

PERSONAL INFORMATION (Please Print.)

Name________________ Citizen of what country?________

Street Address________________

City and State________________ Telephone________

EDUCATION: College Graduate: Yes ☐ No ☐ Degree: BS ☐ MS ☐ PhD ☐

MAJOR SUBJECT:

Electrical Engineering ☐ Electronic Engineering ☐ Mathematics ☐ Physics ☐

Other________________

EXPERIENCE: Primary Specialty________________

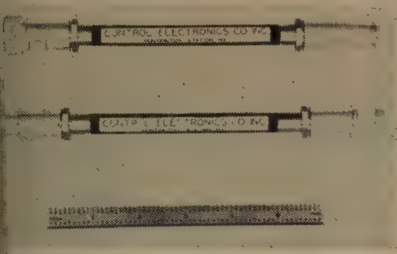
Secondary Specialty________________

YEARS OF EXPERIENCE IN PRIMARY SPECIALTY:________________

Additional Comments, if any, concerning your job interests________________

(*Continued from page 90*)

C.E.C. INTRODUCES NEW LINE F MICROWAVE BANDPASS FILTERS



Control Electronics Co., Inc., who has ently expanded its product line into the crowave field, has introduced a series microwave bandpass filters that features de passbands and very sharp skirts in stop bands.

Typical units are models MWF-102 and WF-103. The MWF-102 has a bandwidth of 7 kmc to 11 kmc and the MWF-3 has a 8.65 kmc to 11 kmc bandwidth. th of the above units have input/output pedances of 50 ohms and a maximum ertion loss of 2 db in the pass band. 5% and 15% of either end of the ssband, the attenuation is 30 db and db, respectively. All of the microwave dpass filters are aluminum cased with rable iridite finish. All inner contors are silver-plated brass. Type "N" nectors are supplied with male and ale at each end.

The filters are priced at $260 each h two to three weeks availability.

rcle Reader Service Card 142

— *mwj* —

LA-685 ALLOY

A new alloy suitable for use in microve cavities, optical structures and other ponents which are normally temperae sensitive has been developed at Genl Communication Company, Boston, ss.

The alloy, properly used, has a maxim temperature coefficient of 0.3 parts million per degree centigrade, as comed with a normal practical value of 1.5 M/° C for Invar, and compared with practical value of 0.5 PPM/° C expeced in fused quartz at normal room perature and above.

Due to the requirement for closely trolled metallurgical processing, it is essary that the Company fabricate the ts in order to assure that they meet stated performance figures.

Applications to date have included waveer cavities, primarily for frequency er service, wherein a very high degree stability is achieved without resorting the use of temperature compensation. Band frequency meter cavities made n this material maintain a frequency ility of ± 1.5 parts per million, per dee centigrade over the range of —40° C + 75° C. Other applications for which material is suitable are microwave rs and missile borne radar-beacon cavwhich undergo a sharp ambient rise ng their operation cycle. A technical sheet describing the material more is available.

cle Reader Service Card 143

the smallest lightest
POWER DIVIDERS
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most complete line too!...

Design features of Transco's Power Dividers include broad bandwidth and low VSWR.

Here are four examples that have 50 ohm impedance, VSWR less than 1.3 to 1, and weigh only 2.5 to 4 oz:

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Type N
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"S" BAND
2700-3500 MC
Type N
Coax Connector
Part No. 40013

"C" BAND
5340-5960 MC
Type N
Coax Connector
Part No. 40009

"X" BAND
8.2-12.4 KMC
Type UG 136
A/U Connector
Part No. 40015

Transco specializes in designing and manufacturing microwave components and systems for transmission control.

Creative microwave engineers ... write for information about your future with this progressive, well established firm.

Send for complete Product Data on Power Dividers and Transco's Coaxial Switches

TRANSCO PRODUCTS, INC.
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Los Angeles 25, Calif.

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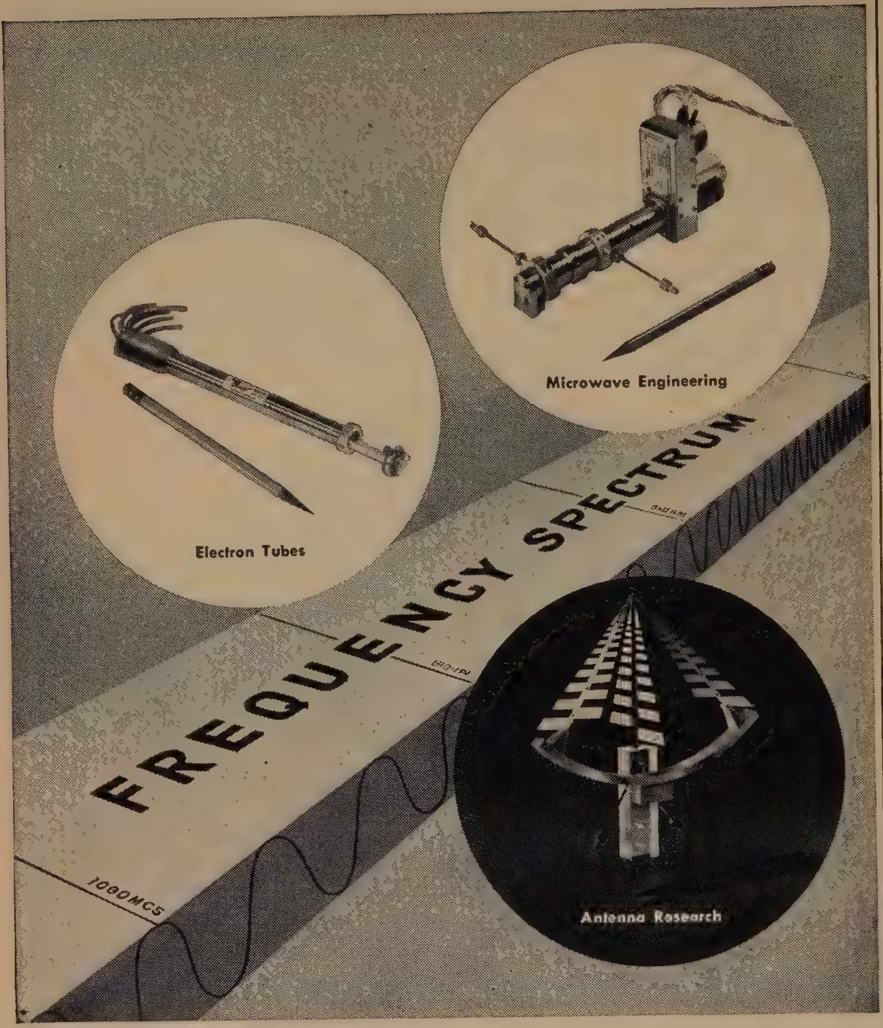

OPPORTUNITIES IN UHF AND MICROWAVE RESEARCH AND DEVELOPMENT

Never before has such high priority been given to microwave research and development . . . never before have the opportunities been so great in this field for the qualified engineer and scientist.

The Research Center of the Bendix Aviation Corporation—The RESEARCH LABORATORIES DIVISION—is expanding its programs in the UHF and microwave field to create interesting and challenging positions for qualified personnel.

Technical openings are now available in the following fields:

ANTENNA RESEARCH in electronic scanning, log periodic antennas, microwave optics.

MICROWAVE ENGINEERING—in ferrite devices, electronically controlled phase shifters, parametric amplifiers.

ELECTRON TUBE research in BWO and TWT from 1,000 to 150,000 mcs.

Investigate these opportunities *now*, where your technical competence and potentialities will receive full recognition in "Building Your Future with Bendix".

If interested, please write or wire Fred A. Barry,
Research Laboratories Division, Bendix Aviation Corporation,
P.O. Box 5115, Detroit 35, Michigan.

Research Laboratories Division
SOUTHFIELD, MICHIGAN

Bendix
AVIATION CORPORATION

New Products

(*Continued from page 93*)

VODICKA CONVERTER ANNOUNCED BY LENKURT

A solid-state UHF and microwave mixe oscillator providing extraordinarily hig mixing gains and low noise has been demonstrated at Lenkurt Electric Company applied research laboratories.

The converter, invented by Dr. Vla imir Vodicka, involves a circuit whic reduces the inherent noise in semico ductors, improves their performance within their previously-known effective operati range and extends it well beyond th alpha cut-off.

For example, at 450 megacycles th Vodicka converter has demonstrated mi ing gains of 40 to 60 decibels at a ban width of approximately 2 megacycles usi a typical MADT transistor costing abo $5. Signal-to-noise ratio with a 1-micr volt received signal is better than decibels.

Such gains have only been achiev otherwise with traveling wave tubes an other special tubes costing hundreds dollars. Conceivably, substituted for the and their power supplies, the Vodicka co verter might greatly simplify the fro end sections and improve the reliabili and performance of VHF and microwa receivers.

The converter can operate either wi the received signal frequency to which t mixer is tuned or with selected multip of that frequency or with combinatio Gains of 32 to 48 decibels are possib when operating with a signal freque equal to $2F_{osc}$ (the second harmonic the oscillator).

By this means it can extend the range semiconductor devices to several times pha cut-off frequencies, and could ma possible new types of diversity and te metry.

Lenkurt, a subsidiary of General Te phone & Electronics, has applied for p ents on the Vodicka converter and investigating its applications.

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The Applied Physics Laboratory
The Johns Hopkins University

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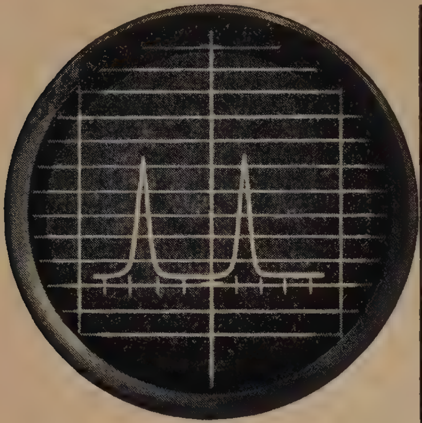
The Applied Physics Laboratory is engaged in significant research and development programs in airborne microwave engineering, especially as related to guidance intelligence for missiles and rockets.

The members of our technical staff work in an academic atmosphere conducive to creative thinking. We offer you an opportunity for theoretical as well as original applied research. You will work with the latest equipment and on assignments which will enable you to advance to the forefront of your chosen field. Your colleagues will include leaders in the microwave field.

Our modern laboratories are located in Howard County, Maryland, equidistant between Baltimore and Washington, D. C. Houses and apartments in all price ranges are readily available, and our location offers you a choice of city, suburban or country living.

For detailed information about these career opportunities, address your inquiry to:

Professional Staff Appointments
The Johns Hopkins University
The Applied Physics Laboratory
8651 Georgia Avenue, Silver Spring, Md.



MICROWAVE ENGINEERS...

There Are Opportunities "Across the Board" ... at Westinghouse-Baltimore

Engineers interested in applying their skills to this rapidly expanding field, will find opportunities in the comprehensive programs at Westinghouse. Westinghouse-Baltimore engineers are engaged in every phase of microwave design and development from components to the largest scale systems on the boards today. These diversified programs have created career opportunities for seasoned microwave experts and beginners alike.

Current Opportunities include:

- Microwave Theory
- Microwave Components
- Receiver Design
- Antennas
- Transmitter Design
- Automated Test
- Systems Planning & Design
- Field Installation & Test

Send resume to: Mr. A. M. Johnston, Dept. 271

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SENIOR MICROWAVE ENGINEER

You will be given system responsibility for the development of new concepts in the generation, propagation and radiation of microwave power for heating, cooking and curing purposes, in numerous commercial and industrial applications. (Raytheon is one of the few electronics companies whose staff includes systems, advanced development, and design engineers in these fields.)

You must have a BSEE or equivalent and should have 8 years of broad design or advanced development experience in the microwave field in order to handle the planned assignments. (Experience in radar development, for instance, or DC power generators or magnetrons.) Since we're looking for an exceptional individual—who will be rewarded accordingly—the deciding factor will probably be your creativeness and ingenuity, as evidenced by: patent disclosures; significant publications; or descriptions of accomplishments not formalized by patents or publication.

MICROWAVE LICENSEE ENGINEER

You will serve as liaison between Raytheon and licensees, assisting in the design of microwave cooking units for these licensees' commercial ovens. This will involve working with the licensees' design engineers to solve such problems as heat, sanitary considerations, microwave distribution, wave modulation, insulation and cost reduction. You will also help translate licensees' suggestions into product improvements.

You should be a senior-level electronics engineer with a BSEE or equivalent and should have 5 years' applicable experience. Background in design of test equipment, high-power modulators, or commercial microwave equipment is especially useful, as is knowledge of magnetrons, underwriters' requirements and FCC regulations. Basically, we're looking for a top design and sales engineer (travel will be limited, however) so salary is commensurate —that is, excellent.

Both positions are in the suburban Boston area and offer attractive cultural, educational and recreational opportunities. Relocation assistance is available. Please phone collect (BIgelow 4-7500) or forward your detailed resume to Mr. Paul R. Alexander, Manager of Professional Personnel, Commercial Apparatus & Systems Division, Raytheon Company, Watertown, Massachusetts.

RAYTHEON COMPANY

Extending existing modulation systems to make more space available in the spectrum, and possibly even broadening the useful spectrum . . . this is a fundamental problem in modern communications. It is the problem to which ITT Laboratories is devoting intensive effort.

At the low end we're designing a new type antenna for very low frequencies. With a conventional antenna this would require a tower more than three miles tall. On the top side — at the high end — we're making radiation pattern surveys for the super high frequency bands. Here the entire antenna consists of a few millimeters of number eighteen copper wire. We're matching these efforts with advances in componentry . . . for instance, the parametric amplifier and now the ingenious ferroelectric converter which converts solar heat to high voltage electricity to power new satellite communications.

If you are a communications engineer who would like to be associated with some of the most significant programs in modern communications development . . . if you would like to work with men who are stretching the spectrum toward direct current at the bottom and the cosmic rays at the top . . . write Manager Professional Staff Relations . . . tell him your interests, your background and the kind of work you would like.

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Expanding the Frontiers of
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ELECTROMAGNETICS

Lockheed Missiles and Space Division maintains extensive research capabilities for the development of antennas and electromagnetic devices for space vehicle applications.

Laboratory studies in antennas and electromagnetic propagation include the application of solid state materials to microwave transmission line component and parametric circuits; the design of antennas to survive the rigors of space flight; and the effects of scattering from missile and space vehicle structures.

Research is also being conducted in the application of MASERS; on problems of radio transmission between space vehicles and Earth; effects of reentry ionization on radio transmission and reception; and development of antennas for data link systems between satellites and ground stations.

Engineers and Scientists

Lockheed Missiles and Space Division has complete capability in more than 40 areas of science and technology – from concept to operation. Its programs reach far into the future and deal with unknown and challenging environments. If you are experienced in electromagnetics or in related work, we invite you to share in the future of a company with an outstanding record of achievement and make an important individual contribution to your country's scientific progress.
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Lockheed / **MISSILES AND SPACE DIVISION**

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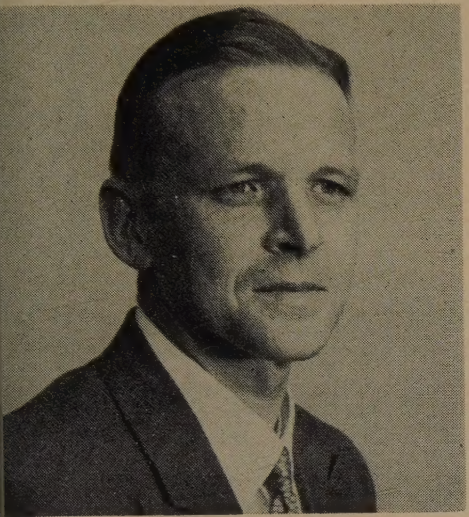
TELECOMMUNICATIONS PROBLEMS IN THE UNION OF SOUTH AFRICA

By **F. J. HEWITT,** ***Director,*** **National Institute for Telecommunications Research, CSIR Johannesburg, Union of South Africa**



FRANCIS J. HEWITT was born in Grahamstown, Union of South Africa, in 1919. He attended Rhodes University, Grahamstown, and was awarded an M.Sc. degree in Physics in 1939. Thereafter he joined a research team at the University of the Witwatersrand working on the development of radar equipment for the South African Forces. During the early stages of the war he gained field experience in charge of stations in East Africa, in the Middle East and later around the South African Cape coast. Thereafter he was appointed to the staff of the South African Military Adviser in London, as radar liaison officer.

Immediately after the cessation of hostilities he was appointed officer in charge of the newly formed Telecommunications Research Laboratory of the South African Council for Scientific and Industrial Research. This laboratory has grown considerably and is now known as the National Institute for Telecommunications Research, of which he is Director. During this period he was awarded a Ph.D. degree by the University of the Witwatersrand for his work on the study of lightning by radar.

Since the installation of the first telegraph system in Union of South Africa in 1860, telecommunications ctice in the Union has followed closely on that of the jor overseas countries, and until recent years the effort ilable for the study of the special requirements of thern Africa has been largely restricted to the local plication of overseas practice.

It was not until 1939, under pressure of war, that the t serious steps were taken within the Union to undere research in a particular field of telecommunications th a view to rendering the country less dependent on erseas sources of supply. Within the organisation of Department of Defence a programme of research on lar, or R.D.F. as it was then known within the British mmonwealth, was commenced at the University of the itwatersrand under the leadership of Dr. B. J. F. Schond, now the Director of the Atomic Energy Research ablishment at Harwell. This programme, which was ed on extremely limited information from overseas, t with almost immediate success, and by late 1940 an erational radar installation for the detection and tracking aircraft had been set up in Kenya by a South African litary unit. This was possibly the first operational radar tion in the Southern Hemisphere. In due course a mber of sets of similar or improved type were built Johannesburg and were used in the Middle East theatre operations, and around the coast of the Union by South ican units until more elaborate systems from the ited Kingdom became available. All the South African lt sets were made from locally purchased stocks of radio and electronic components of the type normally used by Radio Amateurs.

In 1946 the newly formed Government sponsored Council for Scientific and Industrial Research established a number of national research laboratories with the object of ensuring the best use of the country's natural resources and the encouragement of primary and secondary industries. One of these national laboratories, now known as the National Institute for Telecommunications Research, had the specific task of investigating problems in telecommunications which were in any way peculiar to South African conditions.

South Africa is a relatively large country with large areas of sparsely populated land. There are relatively few large centres of population, these being situated either at the sea ports or associated with primary industries, in particular gold mining. Situated at the southerly tip of the African continent it is relatively remote from the major world centres. Thus telecommunications requirements in South Africa are considerable, both in so far as internal and external services are concerned. Landlines have for many years met the country's major requirements for both short and long distance internal communications, and in general there have been no major obstacles in the application of overseas practice for this purpose. The introduction of radio for various purposes revealed the need for a better knowledge of the local conditions: in particular the ionospheric characteristics over South Africa, the ground wave propagation conditions, the magnitude and duration of high atmospheric noise levels, the effect of lightning on microwave systems, the effect of summer thunderstorm conditions on radar coverage, etc.

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Thus the work of the Institute in the early days was directed towards radio communication and the effect of the South African environment. In particular two ionospheric recording stations were established, one in Johannesburg and one in Cape Town, which have continued to operate since then as part of the world-wide pattern of vertical incidence ionospheric stations. The equipment used at these two stations was developed in the Institute and was at that time unique in that the equipment covered the frequency range 1.0 to 20 Mc/sec without any band switching. Since the establishment of these stations the Institute has issued regular predictions of ionospheric characteristics for Southern Africa.

Similarly a special study was made of the intensity of atmospheric noise in the low frequency band, of importance in the consideration of various radio aids to aerial navigation and to medium wave broadcasting. Measurements were made in various parts of Africa south of the equator and the performances of a number of navigational systems under South African noise conditions were assessed by simulating the signals of the various systems and determining the minimum signal/noise ratio required for satisfactory operation.

Ground wave radio propagation was also studied in some detail: a field strength survey on all suitable transmitters within the Union being undertaken.

More recently the Institute's work has been less specifically related to the physical problems of ionospheric communication and so forth and has become more closely associated with equipment and systems. The Tellurometer System of Distance Measurement, which is now in use throughout the world, was invented in this Institute. It is a microwave system based on the comparison of phase of various modulation frequencies. It was originally developed as a survey instrument of high precision, and is the first practical instrument which enables the possibilities of radio wave transit time measurement over large distances to be exploited to the extent allowed by knowledge of the meteorological conditions over the path in question. It has been eagerly accepted by surveyors and civil engineers as a long awaited survey instrument which has completely altered certain concepts. Its possibilities as a scientific instrument for the study of radio wave propagation do not appear to have been investigated fully as yet. Certainly in the early stages of field trials the instrument revealed that many current ideas of radio wave propagation over the earth's surface were not entirely correct, particularly in so far as the forward scattering of these waves is concerned. Similar problems are also encountered in other microwave communication systems, but most such systems provide less information on the excess path length of scattered signals.

The Tellurometer instruments themselves are now in production in Cape Town under a licence agreement. This Institute works in close collaboration with the Company on certain research and development problems related to the Tellurometer and associated fields of work. The first model of the instrument has been exported to a large number of countries throughout the world, and this is the first occasion on which electronic equipment designed and built in South Africa has been exported on an appreciable scale. It is still necessary to import practically all the specialised electronic components as very little of this nature is made in South Africa.

A considerable amount of work has also been done on behalf of the Defence Authorities on the problem of rad coverage and the effect of weather, in particular the hig incidence of summer thunderstorms which is experienc over a large part of the country. Thus considerable emphasis has been placed on the decimetric band and a loc design of radar set has been developed in this frequen region. Work is now in progress on the development parametric amplifiers. This has reached a stage whe early field experience on a radar system is being gaine The Institute is also studying the detailed nature of rad echoes from intense thunderstorms with particular emph sis on polarisation properties and turbulence etc., and al the detailed nature of radar echoes from interstroke jun tion streamers in lightning strokes to ground.

The recent developments in near satellites are bein watched with interest as international communications a of great importance to South Africa, situated as it is the extreme of the African Continent. During the Inte national Geophysical Year therefore South Africa we comed the opportunity of assuming complete responsibil for the installation, operation and maintenance of a Min track satellite tracking station, which was then part the United States Navy Project Vanguard. This station still being operated by the Institute on behalf of the N tional Aeronautics and Space Administration of the U.S.

During the I.G.Y. a particular effort was made to i tensify research in South Africa in those fields in whi international cooperation was essential. A programme ionosphere observations at Rhodes University, the Un versity of Natal and this Institute was carried out on intensified scale. This Institute paid particular attentio to the study of the lower regions using the method partial reflections, and also developed a pulse cros modulation experiment which enabled the results to cross-modulated by an entirely different method.

Until recently the electronic industry in South Afri was a very small one and was limited largely to the assembly of domestic radio receiving sets, public address equi ment and specialised instruments; and to the manufactu of certain components such as chokes, transformers, etc.

During the last few years strenuous efforts have be made to encourage local manufacture wherever there h been an adequate production load. This has been pra ticable particularly in the case of the telecommunicatio requirements of the South African Post Office where t future requirements over a number of years can be es mated with some accuracy. A number of factories ha been established for this purpose. So far these have be mainly restricted to equipment associated with landlin and in this respect overseas practice is in general app cable. In so far as radio and electronics are concerne apart from the assembly of domestic radios and of Tel rometers and associated equipment referred to earlier, t electronics and radio industry remains relatively und veloped.

Thus until this situation has changed significantly, t research problems of importance in South Africa in t field of telecommunications will remain, with some e ceptions, the fundamental ones of radio wave propagati and the effects of the environment. The emphasis m be expected to shift from the ground wave and ionosphe frequency regions to the higher frequency regions whe the spectrum space is less restricted, and where it wou appear the major developments of the future, in so far telecommunications are concerned, are to be expected

Shortly after Waterloo, the Duke of Wellington received a letter, postmarked St. Helena. It was from Napoleon. It read: "Excellency: I was amused to hear your recent remark that 'The Battle of Waterloo was won on the playing fields of Eton.' To have won an engagement in Belgium from a field in England, you must have been further back of the battle lines than I thought.

"The real reasons for my defeat were two, and Eton was neither. In the first place, the radar broke down for two hours in the heat of

*pected to make radar work without Bomac tubes.**

"But I might easily have defeated you, faulty tubes and all, had I not been persuaded to partake of a bottle of Scotch on the evening before the battle. I have reason to suspect my drink was tainted. At any rate, on the day of Waterloo, I did not display my usual energy and decisiveness.

"It appears, in short, that you owe the battle to a bottle. (Signed,) N."

The Emperor received a brief reply by re- of the fact that your loss at Waterloo appears to have been less a matter of Eton than of Drinking, I am withdrawing my original statement. I have released the following in its place, which I here submit for your approval:

'You can mix Scotch and Water
And Water and Scotch
But don't whatever you do
Make the mistake Napoleon did,
And mix Scotch and Waterloo.'

(Signed,) Wellington."

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